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RIFLE PROJECTILES

J. BOUCHER

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A TREATISE

ON

RIFLE PROJECTILES:

IN WHICH

THE APPARENT ANOMALIES AND CONTRADICTIONS EXHIBITED IN THE PENETRATION OF ELONGATED RIFLE BULLETS

ARE ACCOUNTED FOR,

THE BEST FORM OF PROJECTILE FOR DEEP PENETRATION

IS DESCRIBED,

AND

THE MOST EFFECTIVE RANGE FOR SINKING AND PREVENTING THE APPROACH OF HOSTILE BOATS

IS POINTED OUT.

TO WHICH ARE ADDED,

EXPERIMENTAL PROOFS OF THE FALSITY OF THE "MINIÉ" PRINCIPLE, AND THE UNSOUNDNESS OF THE AMERICAN "*FREED* BORE" SYSTEM.

BY

JOHN BOUCHER,

FORMERLY OF THE 5th DRAGOON GUARDS;

AUTHOR OF "THE RIFLEMAN AND THE RIFLE," "RIFLE PRACTICE," ETC.

LONDON:

CHARLES AND EDWIN LAYTON,

150, FLEET STREET.

1856.

[*The Author reserves the right of translation.*]

231. a. 67.


BIBLIOTHECA·BODLEIANA·
DOMINUS ILLUMINATIO MEA

PREFACE.

Having been requested to place upon paper my opinion relative to "the apparent anomalies and contradictions which exhibit themselves in the penetration of elongated rifle bullets," I attempted to do so in the form of a Lecture: but finding, on examination, that my experiments had produced a greater mass of important matter than I had anticipated—and also, that "the best form of projectile" and "the most effective range" were closely interwoven with the subject, I preferred adopting a somewhat more extended form, rather than injure the work by curtailment.

It was impossible, during the early part of my experimental inquiries, not to trace or to imagine, among the variety of facts which presented themselves, certain indications which I believe have served to prop up the strange theories which some writers—through mistaken notions, no doubt—have attempted to establish; and having formed such conjectures, the desire to refute or to verify them gave additional interest to the pursuit. I have not, however, attempted at present to offer a complete enumeration of all the curious and interesting

facts which have come under my notice, as that would have extended the work far beyond the limits I assigned to it; but I have endeavoured to present those which struck me as the most important, either for solving the original question, or for explaining the other subjects which are necessarily connected with it.

J. BOUCHER.

SURREY VILLAS, CAMBERWELL,
June, 1856.

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A TREATISE ON RIFLE PROJECTILES.

In the Report of the Experiments which were carried on at Cork in 1852, it is stated that the power of penetration of an elongated rifle bullet gradually increases, as the range is increased, up to 190 yards.

In order to prove this, experiments were carried on for three days with a variety of firearms, and different sorts of projectiles. On the fourth day the experiments were repeated with the common musket and Wilkinson's rifle. The former, at 40 yards, gave a penetration of 2·25 inches; and the latter averaged 2·75, in a target of green elm. Again: at 90 yards, the musket penetrated 2·25 inches, and the rifle 3·5 inches. At 120 yards, the musket gave 2·5 inches, and the rifle 3·25. Both being subsequently fired at every successive 10 yards up to 220, the result was that the penetration of the musket ball gradually decreased in power as the distance increased, while the elongated bullet gained power of penetration up to 190 yards, after which it slightly decreased.

With reference to the apparent contradictions which exhibit themselves in these penetrations and ranges, Colonel Chesney, who superintended the experiments, observes that "the elongated form experi-

ences, with equal weight, much less resistance than the spherical form; to this, or to some other causes, the increased impetus, which takes place in the early part of its flight, may be attributed." With the view, however, as it appears, of arriving at a more satisfactory explanation of the cause of the increased penetration, he submitted the question to Professor Narrien, of the Royal Military College, Sandhurst; from whom the following answer was received in reply:—

"If the practice of gunnery were not full of anomalies and contradictions, I might have been surprised at what you tell me of the penetration of cylindro-conoidal shot.

"That the common bullet should retain the same penetrating force at distances from 40 to 150 yards, and, after that distance, that this force should diminish, is not remarkable; because, within 40 and 150 yards, the loss of velocity, from the resistance of the air, is not considerable.

"The penetration of the conoidal shot is a mystery; but my opinion is this:—The oblong shot leaves the rifle with the point of its axis a little inclined upwards to the trajectory; the resistance of the air, acting against the hinder part of the shot, gradually forces the axis into the direction of the trajectory; and while this is going on, the penetration may increase as the distance increases, because the conical point becomes gradually more directly forward. After a certain time, suppose beyond distances of 170 yards, the velocity of the shot begins to diminish,

from the resistance of the air, though the point of the shot may be directly forward; and consequently, the momentum and penetrating force diminish considerably with the increase of distance."

Considering the military character of the College from which this opinion emanated, it is, I think, very unsatisfactory. Besides, if we keep the original question steadily in view, it will be found in some parts to be altogether inapplicable, as well as inconsistent with practice. It is thus, no doubt, that, for want of practical knowledge, the man of science, although correct in his principles, sometimes errs in their application. As the cause of the deeper penetration at the longer distances is, however, still unaccounted for, I shall endeavour, with the aid of considerable practical experience, to throw a clearer light on the subject.

In saying that within 40 and 150 yards the loss of velocity from the resistance of the air is not considerable, Professor Narrien states that which every skilful artillerist knows to be incorrect; for, between 40 and 150 yards from the muzzle of the piece, a more rapid diminution of velocity takes place than in any other 110 yards of the range; so much so, indeed, that it becomes at the present day a question of great importance—whether a very high initial velocity can be beneficial or not.

With regard to the latter part of Professor Narrien's reply, it is difficult to comprehend what is really meant. In a range of only 40 yards, a bullet may be said to proceed to the mark aimed at in a

horizontal line; or, in other words, the axis of a proper bullet will maintain nearly a line with the axis of the barrel—the barrel being, of course, held horizontally at so short a distance. At 170 yards, the vertex of the curve will not be more than from 18 to 20 inches above the line of sight; the height to which a bullet will rise, in describing the trajectory, at any of the intermediate ranges, may be therefore easily conceived. At all these ranges, however, the position of a good bullet is so equally favourable to penetration, that the difference, considering the range, is not worth taking into account; but if it were, it would be in favour of the shortest range; whereas, that is, in reality, the one which shows the least penetration. At very long ranges the bullet rises to a considerable height and descends again in its flight to the target; but it is unnecessary to take any further notice of that at present, as long ranges have no reference whatever to the question, so clearly defined in Colonel Chesney's report.

That an oblong shot should leave the rifle with the point of its axis a little inclined upwards to the trajectory, when firing at an elevation, may be easily understood; but that the resistance of the air, acting against the hinder part of the shot, should gradually force the axis into the trajectory (unless the point of the axis had been previously above that line), must be a mystery to every practical man.

The answer, however, from first to last, appears so inapplicable to the subject-matter of inquiry, that I can only account for its apparent obscurity by sup-

posing that Professor Narrien has overlooked the real nature and limits of the question; and has, therefore, introduced into his reply, though somewhat indistinctly, a certain theory which has been connected with the flight of elongated rifle bullets, and which, I believe, originated with Captain Tamisier, of the French Service.

Captain Tamisier's theory has also been adopted by other writers; but as it is totally unsupported by practice with proper bullets, I have no hesitation in declaring it to be erroneous. As it stands, however, in the way of a more satisfactory explanation of the subject in question, I shall endeavour to show where its errors lie; but, in order to do so clearly, it will be necessary for me to point out its peculiarities more distinctly than Professor Narrien has done.

Captain Tamisier, the author of the theory referred to, was of opinion that an elongated bullet, in passing through the air—describing the curve of the trajectory—maintained its axis parallel, in its successive positions, to the position it had at starting; and that the angle formed by this axis with the element of the trajectory—that is, the direction of the motion—changed each instant. That the action of the atmospheric resistance would also be altered by the surface presented by the projectile; as the point of application of this force would not always pass through the centre of gravity, but would establish a rotatory motion different from that with which the bullet was originally animated. In other words: that, by preserving its original position, the bullet

would after a time be pursuing its path with its broadside foremost—that is, with the point of its axis above the line of the trajectory, and the rear end below; this being, evidently, the very position to which Professor Narrien alludes.

To remedy this, and increase the precision of the fire with these bullets, Captain Tamisier thought that it was necessary to create resistances to the atmosphere as far as possible behind their centre of gravity, in order to bring the point of the bullet back to its course. For this purpose he formed a number of circular grooves on the cylindrical part, "in imitation of the feathers of an arrow, which," he says, "are placed at the hinder part to engender resistances."

Colonel Jervis White Jervis, the author of "The Rifle Musket," appears to have adopted the same theory; for in that work he says, "suppose that a bullet describes the trajectory, and A B [that is, A the point of the axis above the trajectory, and B the rear end below] be the position of its axis, it will be seen that the lower part of the bullet re-establishes the air compressed, while the upper part finds itself in the rarefied air: that consequently, the lower part of the cannelures (or grooves) is submitted to the direct action of the air's resistance, whilst their upper part totally escapes this action. The resultant of the air's resistance evidently tends to bring back the point of the moving body according to the trajectory; but as this action is produced by the pressure of an elastic fluid, it results that the point, after having been an

instant upon the trajectory, will fall below, in virtue of the velocity acquired; but then, the upper grooves finding themselves acted on by the action of the air's resistance, this action, joined to its weight, will force the point of the projectile upwards, which will descend to come up again, so that the projectile will have throughout its flight a vertical swing, which is seen distinctly enough in arrows."

From these remarks, it appears evident that both writers allude to the same theory, which Professor Narrien seems to have adopted in his explanation of the position of an elongated bullet in its flight through the air. It will also be seen that the only proof they bring forward in support of this theory is *the construction* and *motion of an arrow.* In doing so, however, they rest their support on what, I shall presently endeavour to show, is very mistaken ground.

An arrow in its flight has been referred to by various authors, and I think justly so, as an illustration of the theory of the flight of a rifle bullet; but it is worthy of observation, that the very points most deserving of study, and which would certainly throw the clearest light on the subject, are either not known by them or entirely misunderstood.

As a practical archer as well as a rifleman, I will venture to assert that the feathers of an arrow are *not* placed on the shaft "to create resistances," as Captain Tamisier says; nor is the "vertical swing" to which the author of "The Rifle Musket" alludes, a characteristic of a good arrow. It is, in fact, the very

reverse, and should only be mentioned in order that its faults may be avoided by arrow makers and the contrivers of military projectiles. Such mistaken notions, however, with regard to the arrow, though somewhat unfortunate in being brought forward in support of a favourite theory, need occasion little surprise; for the celebrated Robins himself was also at fault in some of his remarks. In his "Discourse on Rifled Barrel Pieces," he observes, that "what is advanced with regard to the revolution of a spherical bullet round the line of its direction is further confirmed by the general practice with regard to arrows; for it is well known to every archer, that the feathers of an arrow are placed in a spiral form so as to make the arrow spin round its axis, without which it would be obvious to the eye that the arrow undulated in the air, and did not keep accurately to its direction."

The author of "An Essay on Shooting," in a chapter on Rifle Barrels, makes use of almost the same words. "Archers," says he, "are obliged to feather their arrows in a spiral direction so as to make them spin round upon their axis, for without this they will not preserve their course steadily; and the same obtains with regard to a bullet, or any other body projected through the air with considerable force."

Observations such as these have tended greatly to mislead the uninitiated, by affording room for very erroneous conclusions to be drawn. The skilful archer, however, knows that the fact is the reverse —that the feathers are placed on the stele, or wooden

shaft, in a *straight* direction, in order to *prevent* the arrow from taking a rotatory motion; and that the lighter the feathers are, consistent with strength, the better, being less likely to create resistances to its velocity.

Roger Ascham, who wrote in 1544, objects to the use of certain gay feathers, as being too heavy: he says, "they do seldom keep up the shaft either *straight* or *level*, they are so rough and heavy; so that men who have taken them up for their gay appearance, laid them down again for the sake of utility." He further remarks, that "if the shaft-hand is high and the bow-hand low, or the contrary, the shaft, if it is small, will start—if great, it will *hobble*." Again, he says—"in letting the arrow loose, it must be done so quick and hard that it may be without twitches; so soft and gentle, that the shaft fly not *wabbling*, as if it were sent from a bow case."

Roberts, in his "English Bowman," observes, that "the bow-arm should be held very firm at the moment of loosing; making it, as it were, a vice, upon which the *steady* flight of the arrow much depends."

"If the shooter," says Waring, "holds the string beyond the first joints, the exertion the fingers require to release themselves will force the string out of its position, and, however trifling it may be, will send the arrow *hobbling* wide of the mark."

"The most celebrated fletchers, or arrow makers," Hansard remarks, "were very careful in selecting *strong light feathers*, so as not to affect the balance of the arrow or cause any obstruction to its velocity."

He further says, that "the feathers are to be placed on the shaft *straight* and *even*."

Moseley, in his "Essay on Archery," observes that "the appearance of an arrow on the wing, viewed from one side, is singularly interesting. Its *steady sailing* movement, the curve it describes, its ascending and descending motion, its velocity, &c., are all sources of beauty which never fail to excite agreeable feelings in the mind."

With such authorities as these before us, what becomes of Captain Tamisier's assertion, that the feathers are placed on the shaft to *create* resistances; and also of the "vertical swing," to which Colonel Jervis alludes; and I may also add, what becomes of a theory supported by such erroneous notions?

The position of an elongated bullet in its flight through the air is, I am of opinion, the same as that of an arrow; supposing them both to be equally well and properly balanced. In the arrow the position is easily observed in consequence of its greater length, the greater bend of the curve or trajectory, and the comparative slowness of its flight. A person standing on one side may perceive that, in the ascending portion of the curve, the arrow rises steadily, with its point somewhat higher than its rear end; at the vertex of the curve both ends are on a level; the arrow then turns on its shorter axis and descends with its head inclined towards the target, its centre of gravity being all the time in the line of the trajectory, with both ends above it, forming a tangent to the curve. This position is very apparent when

shooting with Indian arrows of 4 or 5 feet in length; but it may be observed in all lengths, down to the bird-bolts and quarrils of a crossbow—a close approximation to some of our elongated bullets—as the velocity can be reduced sufficiently for the purposes of examination.

An arrow in the act of turning on its shortest axis, when it reaches the vertex of the curve, may be very distinctly noticed when shooting at the popinjay—a very ancient sport, much practised still in the west of Scotland. The bird is placed on a church steeple or on a very high pole, when the archers take their stand near the base and shoot almost perpendicularly. In this sport, well made arrows will be seen, when they reach the highest point, to turn on their shortest axis and come down point foremost; but this is not the case with arrows having their centre of gravity far behind, for they may be seen to fall nearly in the same position in which they ascended, namely, with their rear end nearest to the ground.

That these are also the characteristics of elongated bullets there cannot be a doubt; my experiments, at all events, tell me so. The authorities already quoted clearly show that a *steady sailing* motion is the characteristic of a good arrow; it is also that of a properly balanced bullet, though it moves with a spinning motion round its longest axis. The position of an arrow having its centre of gravity in the line of the trajectory, with both ends above it, forming a tangent to the curve, is also the position of a good bullet; for if the rear end of the axis of the bullet

were to fall by any cause soever below the line of the trajectory, the point, being conoidal, would be raised up so as to form nearly a right angle with that line; consequently, the resistance which the air would offer to that part of the bullet would be so great, that it would not only prevent it from recovering its original position, but would turn it over altogether; for no number of grooves on the cylindrical part—which would form a very obtuse angle with the line of the trajectory—would be able to counteract it. It follows, therefore, that if the point of the bullet were to rise at all, so as to cause its longest axis to leave the position of being a tangent to the curve, the same power which caused it to leave that position would augment the deviation until it turned it over; the bullet would then rotate on its shortest axis and strike the target lengthways, or in any position in which it might happen to be when turning round at the time of impact. In long ranges the bullet would have little chance of reaching the target at all, in consequence of the deviating and resisting influences which would be created.

The "vertical swing," or "hobbling motion," in an arrow, is often caused by bad shooting: but it is also, as already stated, the characteristic of a bad arrow; for, if the centre of gravity be placed too far to the rear, it will be sure to have a vertical swing in front. In like manner a bullet, having its centre of gravity too far in the same direction, will have an *apparent* swing in front; but, on account of its rotatory motion, the point will dip down on one side of

the line of the trajectory and rise again on the other—or, in other words, the point of its axis will describe a circle round that line, and the circle will be more or less as the centre of gravity is more or less distant from the front; it will, in fact, describe a cone: that is, by virtue of the reaction of the atmosphere on the bullet, the axis of which is displaced, the point of the bullet, instead of remaining a tangent to the curve, will traverse a spiral round the line of the trajectory without ever becoming identified with it. Such motions may almost be detected by the ear, from the difference in the noise which the bullets make in passing through the air. With a well balanced bullet, having its centre of gravity in the fore part, this motion, like that in a good arrow, is reduced almost to a nullity, and may be known to the ear by the "sweetness" with which it passes through the air.

Professor Shaw, of Queen's College, Cork, seems to have thought that the earliest motions of a bullet were the most irregular; for, in answer to the question of penetration which was also submitted to him, he says, "I am of opinion that instead of an increased momentum (which, it is presumed, may be the consequence of a rush of air to fill up the vacuum in rear of the projectile), there is no increase of velocity, but a steady diminution of it; and that the deeper penetration is owing to the increased steadiness of the axis of the ball's rotation, at a distance greater than 40 yards."

With the first part of Professor Shaw's opinion I agree, with this exception—that a *steady* diminution

is not, strictly speaking, in this case, a correct term; for in a range, say of 800 yards, the diminution of velocity in the first 200 yards is much greater in proportion than it is in the last 200. Without a very expensive electric apparatus, which may be made, it is difficult to prove exactly what the difference is; but I have found that, in a range of 800 yards, the loss of velocity in the first 200 yards is more than four times what it is in the last 200. And this again will be found to vary, as the velocities of projectiles differ; it cannot, therefore, be called a "steady" diminution.

With regard, however, to the latter part of Professor Shaw's reply, I differ from him entirely. If there is any part of a range through which a bullet moves more steadily than another, or more in accordance with its motion inside a barrel having a regular spiral, it is that part which is nearest to the marksman. It is thus that, in short ranges, the rifleman has not to contend with the various obstacles which stand in the way of the long-range marksman; and it is thus that so few of our riflemen excel at long ranges, the practice necessary to make them long-range marksmen being generally insufficient. In short ranges a bullet moves with an immense velocity; and as the resistance and friction of the air have not time to reduce either its velocity of flight or motion of rotation very low, external influences have comparatively little power over it: but in long ranges, as the bullet proceeds these influences come into full play more and more with an increasing

power; for as the velocity decreases and the rotatory motion lessens, the retarding and deviating powers have a greater control; so much so, that streaks and gusts of wind, which have little effect on a bullet in a short range, have a powerful effect when its powers of motion begin to flag. It is thus that a rifleman, at 1,000 yards, has much less chance of hitting a target 10 feet square than he has of hitting one a foot square at 100 yards.

It has been said by the advocates of such a theory, that the first motions of a spinning top are very irregular; but there is no analogy between the two. The first irregular motions of a spinning top are caused by the jerk with which it is thrown from the hand, and its suddenly meeting with the obstacle on which it after a time spins so motionless. On the other hand, the motion of a bullet through the air is a mere continuation of its motion inside the barrel; for if it does not continue to fly in the same manner it is, in a great measure, owing to its faulty construction, upon which the deviating and retarding influences have a much greater power than on correctly formed projectiles.

There is no necessity, however, for allowing this part of the subject to remain mere theory: proof is easy. Take a small iron target and raise it at any portion of a range, say of 200 or 300 yards, so as to intercept the bullets in their flight. As this movable target should form nearly a right angle with the line of the trajectory, it should be perfectly upright at the vertex of the curve; if in front of that part, it should

incline to the marksman; but if further away, it should incline from him, as all archery targets are made to do. However, in whatever part of the range this target may be raised, the aim should be taken under it at the bull's eye of the stationary target at the extremity of the range; and, as a certain degree of elevation will be necessary, the bullets will rise, and in their flight strike the intercepting target. The remains of the bullets may then be picked up for examination, when any practised eye will easily be able to tell, by their appearance and the marks on the target, whether they struck fair, point foremost, or otherwise.

The best form of projectile for effecting the deepest penetration is the cylindro-conoidal, provided the centre of gravity is placed in the fore part, so as to ensure its flying steadily and true; for unless it does so, it will never be in a favourable position for deep penetration. In solid bullets it is impossible to place the centre of gravity sufficiently forward without adopting a form which would be prejudicial to the velocity, and consequently to the momentum necessary for deep penetration.

In 1852, the Master-General of the Ordnance invited the principal gunmakers of England to lay before the Small Arms Committee "such suggestions as they might consider would be effectually an improvement on the Minié cup." All the bullets which were then submitted were, however, on the "Minié expansion" principle, except two—namely, the inventions of Mr. Wilkinson and Mr. Pritchett.

Mr. Wilkinson's bullet is solid, with two deep grooves round the cylindrical part; but they do more harm than good, for they are not the means of expanding the lead into the grooves of the barrel, as has been supposed. They have certainly the effect of throwing the centre of gravity well forward *before* firing; but as soon as the explosion takes place, they are closed up sufficiently to throw the centre of gravity back again to the rear. Besides, as Colonel Jervis remarks, "the grooves, in closing up, nip the paper of the cartridge, pieces of which the bullet holds during its flight, thus causing very wild practice beyond 300 yards." But supposing that neither paper nor patches were used, grooves on a bullet are very objectionable; for as they are never closed up so as to leave a perfectly smooth surface, the inequalities left are great hindrances to velocity and correctness.

The forces which compel a projectile in motion to stop are generally understood to be, the attraction of gravitation and the resistance of the air; but to these a third may be added—namely, the resistance arising from *friction*. Independently, therefore, of the ordinary resistance of the air on the front part of Mr. Wilkinson's bullet, part of the force which would otherwise carry it through the air at a certain rate is, in consequence of the inequalities on its sides, wasted in producing lateral and oblique motions amongst the atmospheric particles, the effects of which partake of the nature of friction. Every reduction in the amount of friction, and, consequently, of the air's resistance, is attended with a

proportional increase in the continuation of the motion. Render the bullet smooth, and the motion will be considerably prolonged.

A very striking illustration of the resistance which a fluid offers to a rough body may have been noticed in the report of Her Majesty's Steam Transport, *Himalaya*, which arrived at Spithead a short time ago from the East. The bottom of the ship had got so foul, that her speed was decreased nearly $3\frac{1}{2}$ knots per hour. So apparent was her diminished rate of steaming, that even the *Jura* beat her nearly 3 knots in a run of 300.

Mr. Pritchett's bullet is also nearly solid, but it has a better exterior form than Mr. Wilkinson's, with the exception of the base, which in Mr. Wilkinson's is flat, and therefore in that particular, I think, superior. In Mr. Pritchett's "there is a small hollow at the base, for the purpose," as Colonel Jervis says, "of lightening it in that direction, and throwing its centre of gravity forward": but if such be the intention of the inventor, it is of little use; for when the explosion takes place, the base is driven up, and the hollow so much reduced, that the contrivance becomes of little or no service. Colonel Jervis adds, that "the expansion of the bullet is obtained by the force of the powder, when ignited, acting suddenly against the base, driving it up slightly before the inertia of the point of the bullet is overcome, thus causing it to expand throughout its cylindrical part."

In Colonel Jervis' last remark there is true science shown, whatever the real intention of the inventor

may have been: but Colonel J. Clark Kennedy, First Instructor at the School of Musketry, Hythe, seems to have entertained a different opinion; for, in his "Theory of Musketry, adapted for the use of the Troops," he says, "The expansion of the bullet is obtained by the direct action of the gunpowder upon the hollow at the base—as the same result, or nearly so, is obtained, as when the iron cup is used." He also gives a representation of the bullet "as when passing up the barrel," showing "the effects of the gunpowder upon the hollow," which appears much enlarged and *widened* out; but this is evidently a fancy sketch, as the force of the explosion leaves the base of the bullet in the state which I have already described. To this there is a companion sketch, showing the Minié bullet with the cup driven far in, and the cavity much enlarged; but this, I must say, is the only instance in which I ever saw the cavity and the cup of that bullet in such a state.

The essential or chief point, however, which is requisite to make a bullet fly steadily and true, and consequently to effect the deepest penetration, is not one of the characteristics of Mr. Pritchett's bullet, no more than it is of Mr. Wilkinson's; namely, that of having the centre of gravity in the fore part.

A bullet having its centre of gravity too far behind has this disadvantage to contend with, especially at long ranges—in its flight, the point of its axis, as I have before remarked, will traverse a spiral round the line of the trajectory: and, as its velocity of flight and motion of rotation decrease, the resist-

ance of the air will cause these circles to become more and more irregular; and the more this irregularity increases, the more powerful will the deviating influences become, until the bullet is brought to the ground. In this case, there will not only be the force of gravity and the ordinary resistance of the air to contend with, but there will be the additional atmospheric friction, and that of a deviating nature, which is caused by the bullet's circular motion. Consequently, a bullet of the same weight and diameter, having its centre of gravity in the fore part, flying steadily on without any extra obstruction, will range further and more correctly than one having its centre of gravity too far behind; and, as a matter of course, it will require less elevation, and so travel through a lower trajectory, in order to hit the same mark.

According to General Sir Howard Douglas, Colonel Jervis, Colonel Kennedy, and others, the Pritchett bullet was adopted by the Ordnance department in 1852, in consequence of the great irregularities of the "Minié." It continued to be the favourite projectile until lately, when, for some reason or other, which I have never been able to find out, it was discarded, and the old Minié system again brought into use.

A vast deal has been said in praise of the Minié bullet—through ignorance, no doubt, for a careful examination would have shown that the system itself is a complete fallacy. It cannot be called, in some senses, a deception, for Captain Minié certainly believed in it, as do hundreds at the present day; but neither

he nor they could have studied cause and effect, in this instance, with sufficient care. Indeed, with but few exceptions, the system appears to have been simply taken *on trust*, as is evident from the numerous imitations and modifications of the same expansive principle; as, for instance, with iron cups of different shapes, movable metal and wooden plugs, hollows of various forms, &c., all of which are mere modifications, constructed on the same false principles, and hence the cause of their failure. The system may, therefore, be more appropriately called a great delusion.

In almost every modern treatise on the rifle, the Minié system appears to have been admitted as an established fact; though few of the writers seem to know much of the practical workings of the system personally. The theory, however, is very graphically explained by some of them; but unfortunately it will not bear the test of practice.

Colonel Kennedy, in his "Theory of Musketry," published only last year, says, "The cup, acted upon by the force of the gunpowder, is driven violently up the hollow: the unyielding iron, driven upwards, acts as a wedge; and the softer metal, lead, giving to the pressure, is forced outwards, increasing the size of the bullet, so that the bore is filled by its expansion, and all windage completely destroyed."

Colonel Maitland, in his "Instructions in Ball Practice for the Army, Militia, &c.," expresses himself somewhat to the same effect, for he observes that "the principle upon which the Minié bullet is arranged and acts is thus—the bullet is moulded or compressed

in shape somewhat resembling a thimble; a round iron cup is fitted just within the interior, and which being of a conical form, the cup, on receiving the shock of the explosion within its hollow, is forced forward and into the interior sufficiently to spread the bullet the small quantity that is requisite to fill the barrel outwards, and against the inner surface of the barrel, after the manner of opening an umbrella; so that the outward pressure caused by the explosion presses the lead into the grooves, thereby stopping the interval or windage; and in its forward motion the bullet acquires the rotatory motion, so essential to its passage through the air, communicated by the spiral grooves."

Sir Howard Douglas, in his work on "Naval Gunnery," remarks that "the cup being forced further in by the explosion of the charge, causes the hollow cylindrical portion of the shot to expand and fix itself in the grooves, so that the shot becomes forced at the moment of discharge; but unless the cup be driven, by the first action of the explosion of the charge, so far into the conical space in which it is placed as to cause the lead to enter into the grooves of the rifle before the shot moves, there will be no rotation."

These descriptions are, I believe, faithful expositions of Captain Minié's theory, as explained by himself; but practice and experiments tell a very different tale. Between *cause* and *effect* there is a necessary connection; but between the movements of the iron cup in the Minié bullet, and the expansion of the lead

into the grooves of the barrel, there is no connection whatever. The hollows in the bullets, instead of being forced outwards, are in the great majority of cases actually contracted; and the cups, by the force of the contraction, are either held in their original position, canted on one side, or forced out of the bullet altogether—it is, indeed, a rare occurrence to find one driven fairly in. A dozen rounds or more, fired into deep water, and fished out again for inspection, must convince the greatest sceptic of the truth of what I say. Moreover, it is a fact, borne out by practice, that the best Minié shots are made when the iron cup does not move, but is held firm in its original position; in fact, when it turns rebel to the theory of its inventor. It is therefore evident that Captain Minié, overlooking the real facts, has unknowingly attributed the improved shooting to a cause very different from the true one.

It is true that lead will "give," to a certain extent, to pressure, it being soft and inelastic; but even if the iron cups were driven violently up the hollow, as Colonel Kennedy says, that part of the lead which *gives* to the pressure will not, from its softness, communicate the same amount of pressure which it receives to the exterior part of the bullet, next the grooves of the barrel. However, it is evident enough to the careful inquirer, that the driving upwards of the iron cup in the hollow of the bullet is not the cause of the expansion of the lead into the grooves. There are no facts, resulting from practice, which prove this; though certain appearances, without suffi-

cient examination, have been taken as such. On the contrary, sufficient facts attest that those very appearances are the result of the explosion of the charge, which drives up the hinder part of the bullet on the fore part before the inertia of the fore part is overcome; thus shortening it in length, and expanding it in breadth into the grooves of the barrel. The advocates of the Minié theory would have us believe that the tremendous power of the elastic fluid which is engendered by the ignited gunpowder is concentrated on the iron cup alone, the surface of which is not one half of that of the lead which surrounds it, and which is equally exposed to the force of the explosion. Such an idea is simply absurd.

Though the Minié system is considered for the present to be worthy of the principal place in the Government stores, it will be seen, from what follows, that it is admitted on all hands to have grave faults, which detract from the advantages which are supposed to arise from its adoption. It is, moreover, a remarkable fact, that in all the attempts to remedy these evils the falsity of the system itself has never been discovered, and that some trifling modification, on the same false principles, has been the only result.

"Colonel Hay," says Sir Howard Douglas, "has introduced an important improvement in the shape of the cup, and in the figure of the cavity into which it is forced on the firing of the charge. It will be perceived that the cavity in the Minié shot has the form of the frustum of a cone, while that of the cup is a hemisphere: now all who have examined the shot

picked up after having struck an iron target or penetrated into earth, find that the hemispherical cup is very liable to be canted or turned instead of being forced directly into the hollow space; the lead of the shot is not driven equally into the grooves of the rifle. For this evil Colonel Hay has proposed a remedy, in giving both to the cup and the cavity in the shot conoidal forms, by which means the former must, by the force of the powder, proceed directly forward in the hollow space, and thus uniformly expand the lower part of the shot in the bore."

Sir Howard Douglas here admits the existence of certain evils which, though they cannot be detected after the bullet has struck an iron target, may be easily perceived after it has penetrated into earth. In expressing his opinion, however, with regard to the nature of the cure, he has no doubt been unintentionally led into error; for the cause of the improved shooting is simply this—From the peculiarity in the form of the new cup and the cavity, the former is less likely to be canted on one side; the contraction of the cavity in front of it, caused by the explosion of the charge, having more power, from the shape of the cup, in keeping it in its original position. For the same reason, the cup would also be less likely to be thrown out of the bullet; and this again would be so far an improvement, though an unconscious departure from the Minié principle; but so much the better, as more correct practice would result from it.

Colonel Jervis remarks, that "if the cup is not

placed perfectly straight in the hollow of the ball, it is driven in sideways, and does not expand the ball equally in all directions. The cup also sometimes leaves the bullet, either in the barrel or on issuing from the muzzle, and strikes the ground fifty or sixty yards from the marksman." Here again are faults admitted; though I do not concur with Colonel Jervis in the first part of his remarks; for no proofs can be shown that the iron cup is the cause of the expansion of the lead. With the latter part, however, I do agree: and I may add, that the tendency of the iron cups to separate from the bullets is a most serious evil; for they may often wound our own men when employed or moving in advance, though not directly in front of the marksmen.

Colonel Kennedy observes that "the iron cup is not only troublesome and expensive to manufacture, but is at times the cause of wild shooting, from the carelessness of the boys employed in making up the cartridges, not placing the cup evenly in the hollow of the bullet. When this is the case, the cup is driven up slantingly, and the bullet is either imperfectly or not sufficiently expanded, so as to exactly fill the bore." Here, Colonel Kennedy is certainly in error—for want, I presume, of proper investigation. He blames the boys, whereas it is the system he ought to find fault with; for, were the boys ever so careful, the cups would often be canted on one side by the explosion alone. The boys, no doubt, will do harm, when fitting in the iron cups, if they strike the lead as well as the iron; for, in so doing, they in-

crease the diameter of the base of the bullet, which renders the loading a more difficult matter.

Colonel Chesney remarks that "great success has attended the Minié, though it has occasionally the disadvantage of the cup being forced through the ball; a separation of the cup, and rupture at the base, also sometimes occurs, which lessen its effect as well as its precision." The idea of the cup being sometimes forced through the ball is also, I am aware, entertained by others, as well as Colonel Chesney; but my opinion, founded on a careful examination of many specimens, is this — The cup is not forced through, so as to be the means of carrying off the front part of the bullet; but, being either canted on one side, or thrown out of the bullet, the tremendous power of the elastic fluid forces its way through the cavity, carrying with it the front part of the bullet; that part being, in such cases, very probably unsound, as it is impossible at all times to guard against this, either in cast or compressed hollow bullets. In the specimens generally which I have seen, the cavity is lengthened, and also widened out much more than the mere passage of the iron cup would make it; thus clearly showing, by the effects produced, that the violent rush of the fluid through the cavity is alone the cause.

That the "Minié" bullet has many serious faults, none who know anything about it can deny, though few indeed seem to know where the faults really lie. The difficulty in finding these out is also greatly increased by the too general belief in the correctness of

the system, in the truth of its principles. I might quote from other authorities—but it is unnecessary—in order to show how very common this belief is, even amongst military men. So long, then, as its principles continue to be so blindly believed in and followed, so long will the cobbling of the system continue, without ever arriving at any truly beneficial result.

It has been said that bullets having deep cavities in them, sufficiently large to throw the centre of gravity into the fore part, will fire as correctly as those with cups or plugs. To this I have merely to say, that practice proves the contrary; provided the cups or plugs remain *firm* in their original position. What has probably led some persons to think so is this—in firing with the Minié bullet, either with the iron cup or wooden plug, it is impossible to tell how many of these accessories get moved, or are thrown out of the bullet altogether. A fair comparison has therefore never yet been made. "Trials were made at Woolwich, with and without the iron cups, in order to ascertain the possibility of dispensing with the latter. The result showed that the practice of bullets of the regular Minié form, with cups, was fully one third better than that of bullets without cups." But this report is imperfect, inasmuch as it makes no allowance for those bullets from which the cups separated, or were canted on one side; all of which should have been deducted from the list of bullets having cups. This omission, however, anyone may even yet rectify, by firing fifty or a hundred rounds, with

cups, into water, and then, after their examination, concluding what the per centage of faulty bullets might have been when the trials took place.

Independently of the inferior shooting which has always attended the practice with bullets having large exposed cavities, they have faults of a nature so grave as ought to prevent them from ever being recommended for the use of the army. If the cavity be made large enough to throw the centre of gravity sufficiently forward, the sides of the bullet will be so reduced in strength that, in all probability, too many cases would occur in which, as has been already observed, the elastic fluid, by pressing up the *unprotected* cavity, would blow the top of the bullet off; leaving a portion of the cylindrical part in the barrel, and the soldier useless until the barrel was again cleared by the armourer.

Few persons, who only examine bullets previous to firing, seem to be aware of the change which takes place in their form, on the explosion of the charge. A bullet with a large cavity, after leaving the muzzle of the piece, is totally different from what it was before loading; so, much so, indeed, that many persons have taken them to be different bullets entirely. It was very justly remarked by Captain Delvigne, in 1853, that "if bullets were made with cavities, the capacity and form of the hollow *should be proportioned to the force of the charge;* for, when the hollows were large, the power of the elastic fluid often forced its way through, carrying the fore part of the bullet with it."

With respect to foreign bullets, I have already

taken notice of the "Minié," and that is the best the French have at present. The Russian and Prussian projectiles are very bad, and show great want of science in their construction, if intended for long ranges. The Prussian bullet is much less in size than the Russian, but both are short in comparison with their thickness; and conoidal, or nearly conical, in their form; so that it matters little, the centre of gravity being so very near the hinder end, whether they rotate on their longest or shortest axes. In fact, it is impossible, from their peculiar shape, that they can range both far and true. When rotating on their longest axes, the circle which the points of the bullets will describe round the line of the trajectory will be nearly as great as if the rotatory motion took place round their shortest axes: so that they never can be in a favourable position for deep penetration, unless when close to the object; and that, as will hereafter be shown, is not the distance for beneficial effects. In 1853 Colonel Le Couteur instituted what was then thought to be "a very important course of experiments," to determine the relative penetrating powers of different sorts of shot. Among others, there was one proposed by himself, of a shape somewhat like the Russian, and this bullet was declared to have the advantage over the others; but, from the *shortness* of the range (30 yards), the result, as a test, is of no value whatever.

In my endeavours to remedy the evils which have been so often and justly complained of, I attempted the construction of several bullets, particularly with

the view of solving the question—can a cylindro-conoidal bullet be contrived, which will have a flat surface for its base, and the centre of gravity in the fore part? In my attempts from time to time I met with less or more success until I arrived at my last improvement, the principle of which has afforded me so much satisfaction, that I fancy I have only to describe it, to enable any intelligent marksman to perceive at once the utility of the contrivance.

In the end of the bullet, which is a fair cylinder for half its length, I formed a cavity of a conical form, similar to the inside of a small thimble, which stretches forward somewhat more than half the length of the bullet, and which is wide enough to reduce sufficiently the weight of the hinder end, so as to throw the centre of gravity into the fore part, *even after the explosion of the charge takes place.* On the edge of the cavity I made an indentation, or shoulder, about a twelfth of an inch in depth, and upon this I placed an iron disc of the same thickness, which closes up the cavity even with the end of the bullet, making a flat surface of that part; so that it may be called *a hollow flat-ended bullet*, though to all appearance solid.

Experience shows that, when the explosion takes place, this bullet rifles itself admirably; and also, that it preserves its shape until it strikes the target, with the exception of being somewhat shorter, *in consequence of the latter part of the lead having been driven up on the fore part, by the explosion, before the* INERTIA *of the fore part is overcome;* this being the true cause of all expansion in bullets, whatever the advocates of

other agencies may say to the contrary. From the shape of the iron disc, its edge being cylindrical, it does not fall out, though easily fitted in; a pressure of the thumb being sufficient, without tapping. The disc, unlike the Minié cup, performs the duty assigned to it, and in the explosion becomes, as it were, hermetically sealed in its original position. It may therefore be called a *safe* bullet; for I could fire with the greatest confidence, at a distance of from 800 to 1,200 yards, over the heads of bodies of men employed or moving in the intermediate space, without any fear of the iron discs leaving the bullets and by chance striking the men.

In the construction of this bullet care has been taken to avoid the faults noticed in others; and as there is no imitation or modification of other plans, and as the principle is the very opposite of the Minié, it may very fairly be called a British invention.

I have been requested to adapt this projectile to a certain bore, confining myself at the same time to a given weight; but it would betray great want of judgment on my part, were I to attempt such a thing and expect any good to result from it. The principles of elongated bullets cannot be adapted to *different weights*, so as to fit the *same* barrel; or to the *same weight*, so as to fit *different barrels;* for, as this would necessitate an alteration in the *proportions* of the bullet, which, it may be presumed, were found to be the best, the principle of the invention would be as much altered or lost as if it were a different projectile entirely. And here, again, we may very profitably take a lesson

from the art of shooting with the bow. First-rate archers have generally three classes of arrows in their quiver—for particular distances—selected according to the power of the bow, and weighed against silver money at the mint standard weight; thus arrows weigh from three to seven shillings, though seldom shot with above five. But, in altering the *weight*, does the arrow maker confine himself to the *same thickness?* No. He is so particular in his workmanship (if he is a superior maker) that every arrow appears a reduced or enlarged *fac simile* of the other. With elongated bullets there are always certain proportions which will be found to have the best result—the bore of the barrel, and the proper quantity of powder, being taken into account—and experiments alone can determine what these proportions ought to be, without allowing them to be controlled by any particular weight. Few persons think that, whatever the proportions of an elongated bullet may be when put into the barrel, they are very different when the bullet leaves it; and that all these circumstances must be carefully considered and calculated upon in the formation of leaden projectiles.

At short ranges the superiority of any bullet is not so easily perceived as at long ranges; for bullets travel, during a great part of a short range, at a higher velocity than air can rush into a vacuum: consequently, the peculiarities of the hinder parts are not affected by the air rushing in behind. But, at long ranges, the action of the air in rushing in behind the bullet has a great influence in driving some of

them astray; as, for instance, the "Minié," when the cup is canted on one side, or a hollow bullet which is fractured or damaged by the explosion; for, in them, the irregularities arising from the rotatory motion of the canted cup or damaged end will incline the point of the bullet to the right or left, and so drive it out of its course. How often does the very best aim prove of no avail, from such causes! Indeed, the most skilful marksman often makes a bad shot, which he cannot account for; his want of success being entirely owing to a fault in the bullet.

It may possibly not make much difference to regiments of the line, that, in order to enable each man to carry 60 rounds of ammunition, the weight of the bullet should be fixed so low as 530 grains, ·577 bore, as, from the nature of their duties in the field, very correct shooting cannot be expected from them; but, for riflemen, it would be a great improvement to have a heavier, and, of course, a longer, bullet. A bullet of a greater length would have a more considerable mass of lead than another bullet of a shorter length, fired from the same piece. The loss of velocity would therefore be much less with the former than the latter; and, in consequence, the longer bullet might leave the muzzle with a much less velocity than the shorter bullet, and still acquire a superiority over the latter at a very short distance—a superiority in velocity which would give the longer bullet a superiority in penetration. But this applies only to bullets like my own, in which the centre of gravity is placed in the fore part. In bullets so nearly solid as

Mr. Wilkinson's or Mr. Pritchett's, a greater length would be a great evil, as it would cause the point of the axis to describe a greater circle round the line of the trajectory; and, consequently, offer a greater circular motion to the resistance of the air.

A remarkable illustration of this fact occurred during the course of the experiments which were carried on by the Small Arms Committee at Enfield, in 1852; though they do not account for the apparent anomaly as I would have done. The Report says, "An elongated projectile, whether conoidal or cylindro-conoidal, when its axis does not remain a tangent to the trajectory during the whole course of its flight, offers a greater surface to the resistance of the air when fired at any angle, however small, than when fired horizontally. In the latter case it issues from the muzzle in that position in which it is best able to penetrate the air intervening between itself and the target, its leading surface being conoidal only; when fired at an angle, however, the whole length of the ball presses obliquely in its forward movement against the intervening air, the leading surface being partly conoidal and partly cylindrical, if the projectile is cylindro-conoidal."

"What has been stated above may perhaps explain the reason why Mr. Wilkinson's bullet has a shorter point-blank or first graze, and a greater angle at 100 and 200 yards, than Mr. Lancaster's; although, at 300, 400, 500, 600, 700, and 800 yards, it requires a *smaller* angle than the other. Mr. Wilkinson's bullet is shorter, thicker, and lighter than Mr. Lancaster's,

and approaches nearer to the form of a spherical ball; therefore, when fired horizontally or nearly so, as at 100 and 200 yards, the latter penetrates the air with greater facility; but when a greater degree of elevation is required, as at 300 yards and upwards, then the greater length of Mr. Lancaster's bullet is prejudicial to its flight, by offering to the resistance of the air a greater leading surface (in proportion to what it had when fired horizontally) than does the shorter bullet of Mr. Wilkinson."

The theory which is adopted in this Report will be seen to be exactly the same as Captain Tamisier's, which, I have already attempted to prove, is founded on false principles; I shall therefore, in consequence, endeavour to show that the difference between these bullets may be accounted for in a much more satisfactory manner, without any reference whatever to such a theory.

Mr. Wilkinson's bullet is "shorter, thicker, and lighter" than Mr. Lancaster's, and, in consequence of the grooves on its cylindrical part, will be still shorter, in comparison, when the explosion takes place, as the grooves will then be nearly closed up. On the explosion taking place, the plug in Mr. Lancaster's bullet will also generally be closed up to a certain extent; so that both bullets will become as nearly solid as possible, having their centres of gravity in the afterpart. This being the case, the points of the axes of both will, in their flight, describe a circle; or rather, as I said before, they will traverse a spiral round the line of the trajectory: but, in consequence of Mr.

Wilkinson's bullet being shorter and thicker, the spiral it will describe will not be so open as Mr. Lancaster's, as the point of the axis of Mr. Lancaster's bullet will be further from the centre of gravity, which all the time will, in both bullets, be moving in the line of the trajectory. At short ranges, then, Mr. Lancaster's bullet will gain a superiority over Mr. Wilkinson's; as the former, being longer and not so thick, will have a greater quantity of motion or momentum in it than the latter: the greater resistance of the air, caused by the bullet's larger circular or spiral motion, not having had time to reduce it to an equality with Mr. Wilkinson's, until it has ranged 200 or 300 yards. By the same rule (and it is strictly in accordance with the laws of motion), after 200 or 300 yards Mr. Wilkinson's bullet will gain upon Mr. Lancaster's, owing to the larger circular motion of the latter, which, as a matter of course, presents a greater obstacle to the reaction of the air, and consequently causes a greater resistance to its flight; and the longer the range, the more will the difference be. If Mr. Lancaster had contrived by some plan to have thrown the centre of gravity into the fore part of his bullet, the circular motion alluded to would have been reduced to a nullity, and his bullet would then have ranged further than Mr. Wilkinson's, with the same elevation; or, in other words, he would have been able to hit the same mark with less elevation, tracing a lower trajectory, and effecting deeper penetration.

We now come to the third and last part of the subject; namely, the most effective range for

sinking and preventing the approach of hostile boats.

A bullet, in passing through the air, meets with great resistance from the inertia or inactivity of the matter through which it passes. It must drive before it, and put in motion laterally, those particles which lie in the space through which it moves. If the velocity be increased, the resistance of the air will be increased also, for the resistance is nothing else than the reaction of the particles displaced; and, consequently, the more violent the displacement, the more powerful the resistance will be. But the increase in the resistance of the air is not merely in proportion to the increase in the velocity of the bullet; for if it moves with a double speed, each particle of the fluid which it strikes during one second of time receives from it a double force, and therefore offers to it a double resistance. But, besides this, the circumstance of the bullet moving with a double speed causes it to strike twice as many particles in a second: each particle, as just stated, being struck with a double force. It is therefore apparent, that a double speed will cause the bullet to impart a fourfold force to the fluid which it puts in motion. It will put double the quantity of fluid in motion with a double velocity; it follows, therefore, that it will be opposed by a fourfold resistance.

By the like reasoning, it is very easy to prove that a threefold velocity will produce a ninefold resistance—that a fourfold velocity will cause the resistance to be increased sixteen times, and so on;

the resistance varying in proportion to the square of the velocity, until a certain rate of motion is attained.

But it may probably be asked, what connection can the resistance of the air have with the penetration of bullets into wood? The question is easily answered.

Resistance is common to all bodies, whether solid, liquid, or aeriform: it belongs to matter in all its states, being equally a property of the thin air and of the solid rock. It may appear difficult to admit that a thing so light, attenuated, impalpable, and apparently so spiritual, as the air we breathe, should be composed of parts whose leading properties are identical with those of the most solid and adamantine masses; but so it is: for among the properties which are observed to appertain to matter, *weight* and *inertia* hold a conspicuous place; and these properties air possesses as positively as iron, as it refuses to admit any other body to the space it occupies, until it quits that space. Between air and iron there are many intermediate states; we may therefore, with advantage, take a brief view of the effects caused by the passage of a bullet through different bodies until we arrive at the one in question. Let us then next see what the effects would be if the bullet were fired through a dense moist atmosphere.

In firing through a dense moist atmosphere, the resistance of the air is much greater than in dry weather. This is easily proved at *long* ranges. Take a paper screen and place it a little in advance of the target: nearer to the marksman. When firing in a

clear day, the bullet will go through the screen and strike the target; but when firing through a dense atmosphere, the bullet will not even reach the screen —the resistance of the air being, in the latter case, much greater, in consequence of the particles of the atmospheric fluid being pressed closer together by the weight of the incumbent air. The bullet will therefore proceed slower; and the force of gravity, which will not allow the bullet to remain longer in the air, will have drawn it to the ground before it has reached the screen. The greater the density of the atmosphere, the greater resistance the atmosphere will offer; and this resistance will increase in the same proportion as the density.

Let us now pass to the next densest body, and inquire what the effects will be if the bullet be fired into deep water.

If the marksman fires from a height of 40 or 50 yards, nearly perpendicularly, into the water, the motion caused by the impact of the bullet will be comparatively little, and the effects of the resistance of the water on the bullet very slight. But if he stands close to the water, and fires into it from a distance of half a yard, the effects will be a good drenching to himself from the violent agitation of the water; besides, the bullet will be compressed in front, and expanded laterally for nearly the sixteenth part of an inch, by the resistance of the water. In this experiment the marksman cannot use a paper screen; but he may use a very thin broad board, by fixing it at a certain depth below the surface of the water.

The bullet from the longest distance will be found to have penetrated the board; but the great resistance of the water, caused by the increased velocity of the bullet at the shorter range, will have destroyed the velocity of the bullet altogether before it has reached the board, upon which it may be found lying; at all events, it is easy to mark the bullets, so as to distinguish them when taken out of the water.

Let us now proceed a step or two further, and see what can be made with a body somewhat more dense and solid—say, a bank of loose sand. If the marksman fires at a distance of 200 yards, he will find that the bullet will penetrate to a distance of two feet or more; but that little or no injury has been done to the bullet, unless a few scratches made by the friction of the sand. The front part, however, will be somewhat compressed, but not much more so than when fired at half a yard's distance into water. In this case, unless the marker has been attentive, the marksman will have a difficulty in finding the bullet. Let him fire again at 40 yards: he will have no difficulty this time in finding the bullet, for the hole it makes will admit his hand; and he can take it out without digging, as it will not be more than 8 or 10 inches from the surface. If it were originally a solid bullet, he will find it, on examination, to be more than double the diameter it formerly was, and only about a third of the length; turned over as like a mushroom as possible.

Another advance in the same direction will bring us to try a thick solid wooden target. Let the

marksman fire at this also at 200 yards; the bullet will be found to have penetrated three or more inches, according to the nature of the wood; let him cut it out without injury, and he will find that it is both shorter and thicker than it was originally. Fire again at 40 yards: on this occasion it will not penetrate so far; but, on examination, he will find it to be even shorter and thicker than the last, besides being rougher and more uneven.

We have now come to the point that originated the question. What is the cause of the deeper penetration at the longer distances? Before, however, proceeding to answer the question, let us once more make a move, and try an iron target. If the marksman fires at 200 yards, he will be able to pick up just sufficient remains of the bullet as will enable him to say if it hit the target fairly; but if he fires at 40 yards, it will require a very practised eye to discern, from the remains that may be found, whether the bullet hit the target fairly or not.

Experiments were some time ago carried on at Woolwich and other places, with a view to prove the comparative power of penetration in different sorts of projectiles; but the reports of those experiments are worthless, from the fact that the firing was carried on at too short a range—namely, 30 or 40 yards. The best gunpowder, for rifle purposes, is often tested in like manner: a number of boards are set up, and, at a distance of 30 or 40 yards, they are fired into with charges of different sorts of powder. The powder which sends the bullets through the greatest number

of boards is considered the best; but, for the same reason, this test is also of no value.

To experiments like these we owe, no doubt, the statement referred to by Colonel Chesney, that "a bullet has not sufficient *impetus* to go through a ship's side three inches, at 40 yards." With equal want of judgment, the same persons would, in all probability, pronounce the worst powder to be the best, and the best projectile to be the worst; as it is very evident they are not aware that it is *too much* impetus, and not too little, which prevents the bullets from going further at such a short range.

There are some persons, even military men, who imagine that a bullet *gains* in velocity, for a time, after it has left the muzzle of the piece; and in corroboration of what I state, it may be seen, from Professor Shaw's reply, that the same idea was also suggested to him. Such opinions, however, are founded in error, as they are contrary to the laws of nature.

Matter is incapable of spontaneous change. This is one of the earliest and most universal results of human observation: it is equivalent to stating that mere matter is deprived of life; for spontaneous action is the only test of the presence of the living principle. *A body at rest will continue at rest, and a body in motion will go on moving without altering its velocity or direction, until a change is effected in it by the agency of some external force.* The law that a body is thus indifferent to rest and motion is called the *law of inertia*. A body, therefore, endued with inertia, cannot of itself, and

independent of all external influence, commence to move from a state of rest; neither can it, when moving, arrest its progress and become quiescent.

The same property by which a body is unable by any power of its own to pass from a state of rest to one of motion, also renders it incapable of increasing any motion which it may have received from an external cause. If a bullet leaves the muzzle of a rifle with a velocity of 1,500 feet per second, it cannot by any energy of its own change its rate of motion to 1,600 feet per second. This is a direct consequence of that manifestation of inertia which has just been explained; for the same power which would cause the bullet to increase its rate of motion to 1,600 feet per second would also cause it, when at rest, to commence moving at the rate of 100 feet per second. It therefore appears clear, that to *increase* the motion of a bullet, after it has left the barrel, is an effect of the same kind as to change its state of rest into that of motion.

Dr. Hutton, in his Mathematical Tracts, observes that "when a bullet moves with a velocity of 1,600 feet per second, or any velocity above 1,346 feet (the velocity with which air rushes in to a vacuum), it must continually leave a vacuum behind it, and so must sustain the whole pressure of the atmosphere on its fore part, without having any aid from a *counter-pressure* behind." Again, he says, "When the hinder parts of bodies are of different forms, the resistances are different, though the fore parts be exactly alike and equal; owing probably to the different *pressures*

of the air on the after parts. Thus the resistance to the fore part of the cylinder is less than that on the equal flat surface of the cone or of the hemisphere; because the hind part of the cylinder is more *pressed or pushed* forward by the following air than those of the other two figures."

Such remarks may have led many persons to believe that, when the flight of a bullet is reduced below 1,346 feet per second, the pressure of the air rushing in behind will add to its velocity; but the facts are simply these:—

When a body is at rest, the atmosphere presses upon it with a weight of about 15 lbs. to every square inch of surface. That we are not, in ordinary circumstances, sensible of this pressure, arises from the characteristic property of fluids, in accordance with which they press in all directions upon bodies immersed in them; so that if the upper surface of a body, subject to the pressure of the atmosphere, experience a downward pressure of 15 lbs. to every square inch, the under-surface experiences a corresponding upward pressure. If, however, we destroy this equilibrium, by removing or diminishing the pressure of the atmosphere upon one side of any body, we are immediately made sensible of the pressure which is exerted on the opposite side. For instance: if a plate of glass be placed upon the top of a cylindrical receiver connected with an air pump, and the air be exhausted from the receiver, the plate of glass will be pressed down with a considerable force, and, if not strong enough, will be broken in pieces.

So then, when a body begins to move, though the pressure behind will still continue to be 15 lbs. on every square inch, the pressure in front will be greater, in consequence of the resistance which the air will offer to the motion of the body; and the difference will be greater as the motion of the body is more rapid, until it moves with a velocity of between 1,300 and 1,400 feet per second. When, therefore, a bullet leaves the muzzle of the piece with any velocity above that with which air rushes in to a vacuum, it will meet with a very great resistance, which may be considered of a threefold nature: one part of it being in consequence of the *inertia* of the particles of air which the bullet strikes in its course, another part from the accumulation of the elastic air before the bullet, and the third part from the continual and increased pressure of the air on the fore part of the bullet, as the velocity is such as to leave a vacuum behind, thus taking off from that part the ordinary counter-pressure of the atmosphere, and which consequently adds to the whole pressure in front. As the bullet continues to fly, this accumulation of resistance will soon reduce its velocity below 1,346 feet per second, when the air will rush in behind to fill up the vacuum; but in doing so it will add nothing to the velocity of the bullet, as all the time the same amount (viz., 15 lbs. on every square inch) has been pressing on the other parts, in addition to the pressure or resistance caused by the velocity of the bullet; so that, in fact, the same weight of air which rushes in to fill the vacuum will not only press

the hinder part of the bullet during the remainder of its flight, but will continue to do so *after* it is brought to a state of rest. The air, in rushing in behind, though it has no influence in *adding* to the velocity of the bullet, will, by its pressure, prevent so *rapid* a diminution of velocity, during equal portions of time, as that which takes place at the commencement of its flight.

It has been shown that inability to change the *quantity* of motion in a bullet is a consequence of *inertia*. The inability to change the *direction* of motion is another consequence of this quality. A bullet which is faulty in construction is very apt to be driven astray, and, consequently, brought sooner to a state of rest; but make its form more perfect, and its flight, as well as its direct motion, will be considerably prolonged. Hence the phenomenon of a change of direction is to be referred to the same class as the change from rest to motion, or from motion to rest. The quality of *inertia* is therefore inconsistent with any change in the direction of motion which does not arise from an external cause.

As no motion is naturally accelerated, so neither is any motion naturally retarded: the different degrees of increased or diminished velocity depend entirely on the agency of external causes. Any increase in the rate of motion must betray some impelling cause, any diminution must proceed from an impeding cause, as neither of these causes exist in the bullet itself.

The force which the ignited gunpowder generates

—after having put a bullet in motion and produced its full effect—remains, as it were, enclosed in the bullet; and the joint product, of the velocity and of the quantity of matter in the bullet, represents the result: this joint product is termed the momentum of the bullet. In order, therefore, that the bullet should produce the greatest effect, we must move the muzzle of the piece near to the object aimed at; and the nearer we move it, the greater the effect will be, as the retarding influences of the air will reduce the momentum of the bullet every instant afterwards. But then comes the question, which appears to have been entirely overlooked, *will the effects produced be beneficial, or not?*

In forming our opinions of the effects produced, we must guard ourselves against taking a one-sided view of the case, which the examination of the sand or wood alone would certainly be. It is important to remember that time is necessary for the destruction of momentum, or rather of velocity; and the less the time which is employed, the greater must be the effort exerted—or, in other words, "the force requisite for the destruction of any velocity is greater as the time occupied in its destruction is less." It is evident, then, that the bullets which penetrate the shortest distance require less time to do so than the others, and that therefore more force is exerted. This, however, must be considered with reference only to short ranges; for at very long ranges the penetration will be less, in consequence of the reduced velocity of the bullet, which is caused by the longer resistance of the air.

The destruction of velocity is in all cases gradual, and the time employed will depend most materially on the nature of the substance on which the bullet impinges. In sand, more time is required to destroy the velocity; less time in wood; and still less on iron. A stroke of a bullet against an iron target is only intense and brisk pressure, suddenly begun and terminated. The transition may be comparatively slow, as in sand; or it may be exceedingly quick, as on iron; but it will always be gradual, for no body passes from one state of motion to another without going through all the intermediate states. The effects, however, produced by impact, as compared with those produced by pressure, appear so enormous, that they have sometimes been referred to different principles. But the whole difficulty vanishes when the element time is properly taken into account; and thus it is laid down that "the force requisite for the destruction of any velocity is greater as the time occupied in its destruction is less."

When one body impinges upon another, a certain time is required for the communication of the action through the several particles of the latter—that is, a certain time elapses before the parts in the immediate neighbourhood of the part struck are affected by it. Hence it is that even soft bodies offer great resistance, though only for a moment, when struck with violence; as the surface struck cannot yield until the parts beneath or around are displaced. If we strike the palm of the hand flat upon the surface of water, the *momentary* reaction of the water upon

the hand is almost the same as if the surface had been a solid body. When a bullet strikes against a fixed obstacle, the particles of the latter are more or less displaced in offering resistance to its momentum; and this displacement is greater or less in proportion as the cohesive force of the body struck is less or more able to offer resistance to it. Besides, the resisting force is not uniformly or constantly the same, but increases with the increased force of the bullet. This is occasioned by a greater quantity of particles being driven suddenly back in front of the bullet, before their inertia is overcome; thus preventing the bullet from proceeding so far as it might otherwise do. Moreover, there is the change of form, which a leaden bullet is subject to in penetrating into sand or wood. The penetrations, therefore, will no longer follow the rules which have been generally laid down by mathematicians, but will vary according to the new figure which the bullet acquires.

The effects of impact are modified in a considerable degree by the nature of the substances which come into collision. Lead is soft and inelastic; its particles may be pushed to one side and the other, without separating them from the mass. On the contrary, the particles of sand are driven in every direction; the nearest pressing those which are next them on others, until the force of the bullet is expended by their resistance or inertia. The power of the attraction of cohesion, by which the parts of wood stick together, is so great as to require a considerable *momentum* to separate them. This may be noticed in

the action of the wedge. Wood is, however, far more compressible than any other solid substance; for, by a sufficient amount of force, a light piece may be made to occupy less than half its ordinary bulk, so that it shall sink in water. This is due, however, to the fact that wood has a *texture* very different from that of solids in general, being composed of a number of tubes of different sizes, which in green wood are filled with fluid, but in dry wood contain only air; so that there is nothing to prevent the sides of these from being forced together by pressure, and it is thus they make way for the bullet.

If a leaden bullet strikes with great violence, it meets with equal resistance in proportion, which causes it suddenly to spread out, and as suddenly to lose the momentum it had when it first impinged on the surface of the obstacle. This sudden loss of motion is occasioned by the increased diameter and reduced length of the bullet; as it then offers a greater surface to the resistance of the body struck, with less momentum, owing to its shortness, than it had when it first impinged. The motion of the bullet is therefore almost instantly destroyed, in consequence of its altered shape; like a man walking against a strong wind with a closed umbrella before him, when he suddenly opens it to its full extent.

The particles in that portion of a bullet which comes into immediate contact with the obstacle are those first brought to a state of rest: those immediately behind them retain for a time the force of *their* movement, and press directly on the first; those

behind these on *them*, and so on; until the momentum of each in succession is destroyed by the resistance of those before it—the first portion of the particles being forced outwardly, less or more according to the tenacity of the particles of the obstacle struck. The highest velocity at the moment of impact will suffer the greatest resistance, as the particles of the body struck are pressed on one another too suddenly to give way before the momentum of the bullet is destroyed; and this sudden resistance drives back the particles of lead, flattening the bullet more and more as the body struck becomes more dense; and this alteration in the shape of the bullet, as it increases, increases also the resistance to its progress.

This action is illustrated, on a large scale, by the terrible accidents which have several times occurred to railway trains, in consequence of the sudden and complete stoppage of the engine in front, by a fall of earth, by running against a bank, or by other causes. The whole train may be regarded as a single mass, of which the cohesion among the several parts is not sufficiently strong to resist the force created by the momentum of the hinder parts, when in rapid motion; for this momentum of the hinder part of the train causes the carriages immediately behind the engine to be so pressed on by them as to be crushed to pieces. In the terrible accident on the Versailles Railway, in 1842, it is stated that the crushed carriages formed a pile of 30 feet high, so great was the force created by the continued tendency to onward motion in the long train behind them: a striking but

fearful illustration of the motion of the particles of an elongated leaden bullet, when fired at a short distance into a soft substance.

It is evident, therefore, that the diminution and extinction of the motion of the bullet does in fact depend on the *resistance* which it meets with in the substance through which it passes; but, to the resistance which is caused by the particles of sand or fibres of wood having been driven suddenly back upon one another in front of the bullet, there is another cause to be added, which has not yet been particularly taken notice of—namely, the resistance arising from *friction.*

If the surface of a body, instead of being perfectly smooth, has on some places small projecting eminences, a certain quantity of force would be necessary to carry the moving body over these, and a proportional diminution in its rate of motion would ensue. Thus, if such eminences were of frequent occurrence, each would deprive the body of a part of its speed, so that between that and the next it would move with a less velocity than it had between the same and the preceding one. This decrease being continued by a sufficient number of such eminences encountering the body in succession, the velocity would at last be so much diminished that the body would not have sufficient force to carry it over the next eminence, and its motion would thus altogether cease.

Now, instead of the eminences being at a considerable distance asunder, suppose them to be

contiguous, and to be spread in every direction, and also suppose corresponding eminences to be upon the surface of the moving body; these projections, incessantly encountering one another, will continually obstruct the motion of the body, and will gradually diminish its velocity, until it be reduced to a state of rest.

Such is the cause of friction. The amount of this resisting force increases with the magnitude of these asperities, or with the roughness of the surfaces; but it does not solely depend on this. The surfaces remaining the same, the amount of friction also depends upon the *force* with which the surfaces moving one upon the other are pressed together: a double pressure will produce a double amount of friction, a treble pressure a treble amount of friction, and so on. It is evident, therefore, that as the pressure of the bullet, by its expanding form, is increased, a proportionally greater force will be necessary to carry it over the obstacles which it has to encounter; and, for this reason, it will the more speedily be deprived of its velocity and rendered motionless.

It will be evident to any man who carefully examines a number of bullets when taken out of wood—if he be a judge—that the amount of friction on those which penetrated the shortest distance must have been enormous. It has been found that a sixpenny nail, driven to the depth of only one inch into dry oak, required for its extraction a force of 557 lbs.; and when driven into dry beech, a force of 667 lbs.: so great was the friction on its sides. But when nails were allowed to remain in the wood for some

time, the friction was so greatly increased by the *roughening* of the surface, through the formation of rust, that the force required to extract them was, in some cases, so much more increased, that they broke in the attempt.

In like manner, the comparative friction which bullets undergo in penetrating into wood may be inferred, not by extracting them with the common drawing rod, for that would be impossible; but by the following method:—Cut the wood carefully from *behind* the bullets, and bore holes through them towards the front of the target: through these holes a very strong wire, the size of the hole, having a flat head at the end, the size of the bullet, should be inserted. Then, by applying a sufficient force to the other end of the wire, an idea may be obtained of the comparative amount of friction which the bullets underwent in the course of their penetration. In such a case, the bullets which penetrate furthest will be found to be the *easiest* drawn; and this seeming contradiction is easily accounted for. In consequence of the original shape of the bullets which penetrated furthest having been less altered, they met with less friction in going in; for the same reason, they meet with less friction in being drawn out.

From all that has been stated, it may safely be concluded that, in order to effect the deepest penetration into wood, the marksman should not approach *too near* to the object; *as the result of too much momentum will be as bad as too little.* A range of 200 yards—or a little more or less, according to the

weight of the projectile, from the same bore—will be found to be the most effective. A range of 300 yards will also be more effective than a range of 100 yards, as the extra friction in the wood, caused by the altered shape of the bullet at 100 yards, will have a greater retarding effect than the loss of momentum caused by the resistance of the air during a passage of 300 yards. For the same reason, a range of 400 yards will be equal to a range of 40 yards—in fact, a range of 500 yards will be nearly as good; besides affording a greater chance of cover to the marksman, with more room for an extended formation, from which all the shots may be concentrated on one point, without the men being in the way of one another.

It has been said that it is of no use training soldiers to fire at longer ranges than 500 or 600 yards; but, granting that those who say so are right, and that they take a correct view of the case, are *rifle* regiments to be included in the same category? Surely not! The rifleman's practice should commence where the others leave off; and from 600 to 1,200 yards, and even more, his practice should be incessant. He should always be at work on such a scale, that, when the actual occasion comes, as it may sooner or later, he will only have to do what he has been doing every day; for no man but a thorough rifleman knows how soon the want of practice puts the very best shot out. We have arms and ammunition which prove effective at all these ranges, and we know that men *may* be taught to use them; but we seldom hear of a man who can do so.

Hitherto, the artillery have been considered the only scientific marksmen. Now, a rifle regiment (not in *name* only, but in reality) will have a claim to equal rank; for there is quite as much skill required in laying a rifle, at long ranges, as in laying a piece of ordnance. The elevation must be calculated with as great nicety; the state of the atmosphere must be considered with equal attention; and the effects which the wind may produce, at different parts of the range, must be studied with as much care. There is, in fact, *more expertness* required in aiming with a rifle, in consequence of the greater minuteness of its parts, and the difficulty which is experienced in keeping it perfectly steady at the moment of discharge.

We have seen, on the one hand, that there are men of great scientific acquirements who sometimes fall into error for want of sufficient practical knowledge. On the other, it is but too evident that practical men generally do not understand or duly appreciate the principles upon which the true art of rifle-shooting depends. Into the cause of this I will not now stop to inquire; but I mention the fact, in order that it may be impressed on the minds of those who may wish to become expert marksmen, that, if they desire to bring their practice to anything like perfection, they must avail themselves of the aids which science offers; and that, if they desire to realize all the advantages which science is capable of placing within their reach, they must make themselves acquainted with the connection that exists between the scientific principles and the art.

Any soldier may certainly become a very good shot, at moderate ranges, by practice alone, and be able to perform with some degree of effect the ordinary service that may be required of him: but no man can have any pretensions to the name or rank of a RIFLEMAN who has not obtained a just knowledge of the principles of the art, either by personal experience or regular tuition, or, more properly, from both; for without such knowledge he never can act so efficiently in the field, and for a plain reason—if he only learns his lesson as it were by rote, the least change of circumstances will put him out; for, be the rules ever so general, cases will arise in which they must be varied in order to apply; and if the man only knows the rules without knowing the reasons, he must be at fault the moment he is required to make any new application of them. Indeed, when taking a cursory glance at the great improvements which have been made, we are constrained to acknowledge that every step in this direction confers additional power on the educated and intelligent man over the mere drilled automaton of an ignorant soldier.

ON THE NATURE, AND TRUE CAUSE, OF THE EXPANSION OF THE BULLET INTO THE GROOVES. THE AMERICAN "FREED BORE" SYSTEM, &c.

At page 20 I have said that the "Minié expansion" system is a complete fallacy; and, at page 31, that the expansion of the lead into the grooves of the barrel is caused by the hinder end of the bullet being driven up on the fore part, by the explosion, before the *inertia* of the fore part is overcome. With reference, however, to the latter assertion, I do not wish it to be understood that I agree with those who believe that the expansion takes place *at the instant* the bullet is moved from its state of rest; on the contrary, I am of opinion that a very slight degree of expansion, *if any*, takes place at that moment, and that it is not *complete* until the bullet has travelled up some portion of the barrel: in fact, that the particles of matter which compose the hinder part of the bullet travel, for some space of time, though infinitely short, and through some portion of the barrel, at a *quicker* rate than the particles which compose the fore part; the latter portion continuing to be driven up closer and closer on those which travel before, until the force of the gases have no longer any power to drive the particles closer together; the expansive force of the powder, and the velocity of the bullet, becoming then very nearly equal.

This is no mere theory, unsupported by facts; for during the course of a very interesting series of

experiments, which I had the pleasure of conducting, the truth of it was proved to the entire satisfaction of several parties who attended. The evidence produced also proved in the clearest manner the falsity of the "Minié expansion" principle, as also the unsoundness of the American "*freed* bore" system.

In the course of these experiments, and in order to test the theory thoroughly, some hundreds of rounds were fired, with various sorts of projectiles, and with different lengths of barrel, into water, clay, and other substances, so that the bullets might again be collected, for examination afterwards. The first number of rounds fired were from a rifle barrel 2 feet 8 inches in length. Then, after every firing, from three to four inches were cut off the barrel, until it was shortened to one half its original length. Two inches at a time were then cut off, until the barrel was shortened to one fourth; after which, one inch each time was cut off; and then half an inch, until the barrel was shortened close to the charge. The result showed that, after a certain length had been cut off, the appearance of rifling on the bullet grew more and more indistinct, until not a vestige of it could be traced. A full charge of powder was used at every round.

By beginning at the breech end of the barrel, the evidence may be summed up in this manner. Until the bullet had moved about half an inch, no perceptible signs of expansion had taken place, nor were there any traces of rifling on the bullet. Then, however, the faintest trace of rifling, like scratches, could

be perceived, for about an eighth of an inch, next the base of the bullet. This impression showed itself more and more distinctly, and at greater length, as the bullet proceeded further, until it appeared complete all along the cylindrical part. From the proofs which were exhibited in the earlier stages, the compression of the bullet and the expansion of the lead into the grooves must have continued for some time after, though not discernible on the outside of the bullet. This opinion was further confirmed by the action of the hollow bullets, the cavities of which continued to be more and more *contracted* as the bullets passed farther up the barrel. This was evidently occasioned by the increasing and accumulating pressure of the gases on the hinder end, and the condensed air in front, of the bullet.

The last remark is borne out by the fact that the *front* part of the bullet, during its earliest stages, is quite as perfect in shape as when it issued from the mould; but, as it approaches towards the muzzle, it is resisted by the condensed air in the barrel, and a portion of the conoidal part of the bullet, which was not originally cylindrical, is made so by this resistance, and the great force which presses it on; and this new formation becomes also equally well rifled with the rest; so that, in fact, bullets having a conoidal front when put into the barrel generally leave it with one approaching more nearly to the hemispherical form. It is true that conoidal bullets, when fired into a soft substance, will become flattened or rounded in front, and more so as the force

with which they are impelled is greater; but nothing but the action *inside* the barrel could impress the *rifling* on the new part. This peculiarity begins to show itself when the bullet has passed about a third way up the barrel, and, although hitherto unnoticed by any other writer, is a clear proof of the immense resistance which a bullet meets with from the condensed air in passing up the tube, independent of the friction arising from its rubbing against the sides of the barrel. And this friction, again, it is evident, is greatly increased by the condensation of the air; as the bullet is rendered *thicker*, and therefore presses with more *intensity* on the sides of the barrel.

In further explanation of the remarks contained in pages 21, 23, 26, and 28, relative to the iron cups and wooden plugs being forced out of the Minié bullets, it may be here stated that such separation does not take place at the breech, but as the bullet is approaching the half length of the barrel. When the bullet is first moved from its state of rest, there is nothing whatever to derange the position of the cup or plug; but as the bullet proceeds, the accumulation of the gases become a more powerful propelling force, and consequently the condensation of the air, in the tube in front of the bullet, rapidly increases its resistance. The consequence is, that as the expansion of the lead into the grooves becomes more and more complete, so also does the expansion in the opposite direction *inwardly*—that is, the cavity becomes more and more *contracted* as the bullet proceeds up the barrel; and the force of this contraction loosens, or

rather *squeezes*, the cup or plug out of its place; so that, when the bullet leaves the muzzle, these contrivances fly *after* it, indifferently to the right or left, but often to a considerable and dangerous distance.

Experiments show that a very small per centage of the iron cups or wooden plugs ever arrive at the target *in* the bullets, and that those which do remain firm have no connection whatever with the expansion of the lead into the grooves. It may therefore be said, *literally*, that the labour of preparing them is just so much time and trouble "thrown to the winds." That the public generally should believe in the "Minié" system is not to be wondered at; but that really talented men, like Captain Minié, should continue to do so, without some unquestionable evidence in its favour, is matter of much surprise to me, as well as to some others.

In order to leave no room for mere speculation on the subject, these experiments were carried on with powder from various manufactories;* it was therefore satisfactory to find that, if the movements of the bullets from first to last (though at variance with the opinions of many at the present day) were consistent with the theory that a bullet is not *instantaneously*

* One of these powders appeared superior to the others for *rifle* purposes; but it would be unfair to particularize it at present, as some others, which may be equal, if not superior, have not yet been tried. In another work, however, which I have in hand, I intend to devote a chapter to the subject of rifle powder, and shall then have an opportunity of making a few remarks which may be useful to riflemen generally.

expanded into the grooves at the breech, this theory was further confirmed by the *action* of the powder; for as it was evident that the motion of a bullet, when passing up the barrel, though it may be exceedingly quick, *is always gradual*, it was equally clear that all the parts of the charge are not ignited simultaneously, *but successively*. This was obvious to everyone present; for as the barrel became shorter, larger portions of the powder were blown out unburnt, and afterwards collected and fired again; though the great velocity of the flame, which must have enveloped and consumed a quantity of the loose grains *after* they left the muzzle of the piece, prevented anything like a calculation being made of the amount really consumed *inside* the barrel.

Experiments, however, clearly prove, that though powder explodes so suddenly as to appear a simultaneous burst of flame, it is, correctly speaking, not so, but merely the rapid ignition and combustion of all the particles; and that a portion of time is necessarily occupied by the flame, however short that portion of time may be, in travelling from the first grains to the last. It is evident that a part only of the charge is at first inflamed, but as the combustion proceeds the powder is decomposed, and produces gaseous and solid bodies; and, as the gaseous parts have a tendency to fill a much larger space than that occupied by the powder before inflammation, they seek an outlet where there is least opposition. This outlet is the place occupied by the bullet. The gases, therefore, as they increase, act more and more forcibly

on it, and compel it to exchange its state of rest for one of a very rapidly increasing motion; but it is not until the bullet has traversed a considerable portion of the bore of the barrel that it is subjected to the greatest action of the powder, by the accumulation of the gases. This propelling force, increased by the successive inflammation of the other parts of the charge, thus acts upon the bullet with a continually increasing urging force, and continues to do so (if the quantity and quality of the powder is regulated according to the length and calibre of the barrel) until just before it leaves the muzzle, when it is at its greatest velocity.

The gases engendered by the smallest possible quantity of powder are quite sufficient to overcome the *inertia* of the entire bullet, and to set it in motion, though not sufficient to press the particles of lead closer on one another. The fourth part of a grain will drive a properly fitting bullet up the barrel a distance of three or four inches; a half grain will drive a bullet up a distance of eight or ten inches; and one grain and a half will drive it out of the barrel altogether. Lesser quantities than these would do the same thing, were it not for the great amount of friction which the bullet has to contend with in passing up the barrel. This friction retards, and, as in the case of the smaller quantities of powder, finally extinguishes the motion before the bullet is out of the barrel.

By the *inertia*, or inactivity, of matter, is understood the impossibility of bodies changing their con-

dition of motion or rest without the aid of a particular cause which acts upon them at the instant when they change their condition. Thus, a body is perfectly passive in submitting to any condition in which it is placed, whether of rest or motion. When at rest, it shows an inability to move; and when in motion, it shows an equal inability to come to a state of rest; in the former case, the slightest force which solicits it to move, if not opposed by an equivalent force, is obeyed —the slightest *additional* force is in like manner obeyed, and a greater degree of velocity is the result; in the latter case, the slightest obstacle which retards it, as friction, takes away something from its velocity, and, if such action continue, will finally extinguish the whole motion.

The *inertia* of the particles which compose the fore part of a bullet, as well as the motion of the particles of the lead generally, can hardly be misunderstood, if a little attention be given to the following illustration:—

When a railway train is first put in motion by a locomotive engine, *pushing it behind*, its movement is very slow; its speed is gradually increased, however, and at last it is raised to the full amount that the engine is capable of producing. Now let us examine the nature of this simple and familiar operation. The railway train is a heavy mass of matter, which, by its *inertia*, would remain at rest for any length of time, unless some power were applied for the purpose of moving it. But the engine is placed behind, the steam put on, its power applied, and the train begins

to move very slowly; those carriages nearest the rear being pressed closer together than those nearest the front, in consequence of the inertia of the greater number of carriages which have to be *driven* before them. The motion of the train gradually becomes faster: why is this? It is due to the spontaneous continuance of the motion first communicated to the train (the friction and resistance of the air not being taken into account), and to the continued addition of new force exerted by the engine. During every instant, therefore, the train is carried on by its own tendency to keep moving, at the rate which it had acquired the instant before; and it is also *constantly* receiving a *constant* addition of new force from the engine. Its rate of motion, therefore, gradually increases, and the train continues to move faster and faster; the carriages pressing closer and closer on one another, *but more so in the rear than in the front*, until the full amount of speed is attained.

The preceding example affords a very good illustration of the principle of inertia, inherent in the particles of matter which compose an elongated leaden bullet; at least, until the condensed air in the barrel begins to operate on the front part of the bullet. There are many other examples equally familiar; but this ought to be sufficient to bring home to the mind the general principle, that motion once communicated to a body has a tendency to continue, and that it can only be *increased* or *diminished* by a force applied to the body in the direction of its movement, or opposed to it. Hence we see the truth of that part of the

law which states (page 43) that bodies will persevere in a state of *uniform* motion, unless affected by some external force.

By *uniform* motion is meant a movement continued always at the same rate; that is, the same amount of space passed over in the same time. If a body in a state of uniform motion have a new force applied to it *for a moment*, it will have its motion increased by the same amount which the force would have produced had the body been at rest. Every successive impulse it may receive will act thus upon it. We may conceive, for example, a heavy smooth iron ball to be rolling along a surface of ice (in which case its friction will be very small), and to pass in its course a number of persons provided with bats, each of whom gives it a stroke equal to that by which it was at first impelled. The rate of its motion, therefore, will be progressively increased to twice, three times, four times, &c. the rate with which it started, in proportion to the number of additional impulses it has received. An increasing motion of this kind is said to be *accelerated.*

The action of a charge of gunpowder upon a bullet appears to be exactly similar; but, from the rapidity of the blows, as it were, it is difficult for the mind to imagine that there is any interval between the impulses. We must, therefore, consider it as a new force *continually* operating, like the force of gravitation; instead of being applied at intervals, it will be continually increasing the velocity with which the bullet moves: the first grains firing those contiguous,

and they the next successively; producing a greater and greater amount of expanding force, until the bullet leaves the muzzle of the piece. Such a regular increase must take place in the application of gunpowder inside a barrel in propelling a bullet; and the motion of a bullet, whose rate is thus being constantly and regularly increased, is said to be *accelerated* on a *graduated* scale.

I have alluded elsewhere to the American system of *freeing* the bore; that is, making the bore of the barrel *wider* at the breech end than at the muzzle. This system is founded on very unsound principles; for, whatever its merits may be as regards fowling pieces with small shot, it is altogether false when applied to rifles. With this single remark, the "freeing" system might be passed over as unworthy of further notice, were it not that it is now beginning to be largely patronized in this country, as well as another very erroneous importation—namely, a method of *deepening* the *grooves* towards the breech—or, in other words, making them deepest at that end: decreasing constantly as they approach the muzzle of the barrel.

It is very easy to see that the freed-bore system had its origin in the idea that a bullet is *started* from a state of rest with an exceedingly high velocity; much higher, indeed, than that with which it leaves the muzzle of the piece. Mr. Chapman, the author of "The American Improved Rifle," in his description says, "this weapon, so elegant in appearance and accurate in performance, was first manufactured and

presented to the notice of the public in the year 1841, by Edwin Wesson. Its unsurpassed accuracy is acquired by a more careful attention to the requisites in combination, *the observations and deductions of Robins being almost literally personified.*" How far these observations and deductions may be, in some instances, a recommendation in the construction of a rifle, we shall presently see. Mr. Chapman, however, admits that "this weapon, since its first appearance, has undergone considerable alterations in *construction*, *combination*, and mode of sighting, in compliance with knowledge necessarily gained from its use in regular practice and extensive experiments; and is at the present time (1848) *continually receiving additions and alterations*, as *deficiencies* and *superfluities* are found to exist" (!)

According to Mr. Robins, the force of fired gunpowder consists in the action of a permanently elastic fluid, suddenly disengaged from the powder by the combustion — similar in some respects to common atmospheric air, at least as to elasticity. He showed, by satisfactory experiments, that a fluid of this kind is actually disengaged by firing the powder; and that it is *permanently* elastic, or retains its elasticity when cold, the force of which he measured in this state. He also measured the force of it when inflamed, by a most ingenious method, and found its strength in that state to be about 1,000 times the strength or elasticity of common air, or 1,000 times stronger than the pressure of the atmosphere.

The pressure of the atmosphere is about 15 lbs.

on every square inch; and therefore 1,000 times this, or 15,000 lbs., is, according to Mr. Robins, the force or pressure of the flame of gunpowder, at the moment of explosion, upon a square inch—which is equivalent to six tons and a half. But Dr. Hutton afterwards found, by his experiments, that Mr. Robins was in error with regard to the *heat* of the flame—that it was, in fact, double what he supposed it to be; and therefore, that the strength of inflamed gunpowder, when fired, or *while the flame occupies only the same space as the powder did before it was fired*, is, on a medium, about 2,000 times stronger than the elasticity of common air, or 2,000 times the pressure of the atmosphere: being equivalent to thirteen tons on the square inch. From experiments which were made in 1815 and 1816, and also at a subsequent period, it appears that the pressure on the square inch is even more than 2,000 atmospheres.*

Mr. Robins, in his "New Principles of Gunnery" (vol. i. p. 74), *assumes* that "all the powder of the charge is fired, and converted into an elastic fluid, *before* the bullet is sensibly moved from its place." He also says, "gunpowder fired in any space acts nearly in the same manner as a quantity of air would do, which was condensed a thousand [2,000] times

* Several authors who have since written on gunpowder have erroneously stated that the pressure is 2,000 *pounds* on the square inch, instead of 2,000 *atmospheres*. This has led a writer lately to suggest that "if Government were to hold out sufficient encouragement, the problem of a new and greatly increased force might easily be worked out." (!)

more than the common air we breathe; and which, in that condensed state, filled the same space that was taken up by the unfired gunpowder": and, "hence it follows, that the pressure of the powder on the bullet grows perpetually weaker and weaker, as the bullet is farther impelled before it; for as the bullet is impelled forwards, the inflamed powder takes up more room, and consequently its elasticity is diminished." This is the opinion of many at the present day: that it was the belief of the contrivers of the "freed-bore" system, they themselves admit. Mr. Chapman, in one of his "principles upon which a rifle ought to be constructed," takes it for granted (because Mr. Robins "assumes" that it is so) that "a bullet is *instantaneously started from a state of rest*, with a velocity of 5,000 feet per second"; this being the velocity with which, as it is generally understood, powder expands itself, "supposing it to be *all* inflamed, and confined in the *same space* which the powder filled before it was fired." Mr. Robins, however, believed this velocity to be probably nearer 7,000 feet per second. Bernoulli and Euler believed it to be still greater; though Dr. Hutton found it to be much the same as Mr. Robins, namely, between 6,000 and 7,000 feet per second. But be this as it may, an *instantaneous* velocity of even 5,000 feet per second would be enough to force a leaden bullet not only into the grooves, were they ever so much freed, but out of them again, and into all manner of shapes: but this, we know, is not the case; for experiments show that a bullet, in passing up the first few inches

of the tube, is more in accordance with its original shape than it is when passing up any further portion of the barrel.

Mr. Chapman, in his treatise, occasionally refers to Dr. Hutton's works: but had he studied that celebrated author with a little more care he would have found that he corrected Mr. Robins in many particulars, especially on this very point; for, with reference to this subject, he distinctly states that "though the time of firing is manifestly very small, yet it must be acknowledged that the powder is not all inflamed *in an instant*, both from the circumstance, in the higher charges, of many grains being blown out unburnt, and the velocity of the ball being very sensibly below what it ought to be, on the supposition of the *total and instantaneous* inflammation." He further says, that "Mr. Robins and other authors have only *guessed* at rather than determined the curious circumstances of the first force or elasticity of the air resulting from the fired gunpowder, and the velocity with which it expands itself: these are circumstances which have never before been determined with any precision."

In explanation of his "third principle," Mr. Chapman tells us that "it is desirable to give a bullet as much velocity as it can safely be started with *at the breech*, and the limit of this velocity is the liability of the bullets to upset." This is quite in accordance with Mr. Robins' doctrine, that a bullet is *started* with a higher velocity than it leaves the muzzle; that, in fact, the velocity of the bullet *decreases* as it

proceeds up the barrel: therefore, in order to obtain a high velocity on leaving the muzzle, a much higher velocity is necessary at starting. This is not only very erroneous doctrine, but very bad advice, on the part of Mr. Chapman. In the first place, there is no charge of gunpowder which we could apply that would upset a rifle bullet *at* the breech, though it might do so a little way up the barrel. On the other hand, the recommendation to apply a very great force at the breech is like placing a railway carriage on the line, and firing a 60-pounder at it to make it go forward. A single man, by applying his force, might move the carriage, and, by *continuing* the same force, would make it go faster and faster; but the force of the 60-pounder would only shatter the carriage in pieces, or go right through it without moving it at all. Which agent, it may be asked, applies the greatest force—the man, or the cannon-ball? The question is absurd: yet not more so than the advice to apply a great power to *start* a bullet at the breech. It is, in reality, neither more nor less than a recommendation to *kick* it out of the barrel; and this may, in a manner, be done by using very fine quick powder. But would the result be beneficial? Certainly not. Give the bullet as much velocity *on leaving the muzzle* as a beneficial range may prove to be the best, and leave the velocity, *when starting at the breech*, to the laws which govern the ignition and combustion of the powder.

In fixing on a proper charge for any rifle, the *quantity* and *quality* of the powder should be regu-

lated according to the *length* and *calibre* of the barrel. Very fine powder will cause very rapid combustion, on account of the smallness of the grains, creating an *almost* instantaneous explosion; but this very quickness is its worst recommendation, so far as rifle shooting is concerned. The explosion of fine-grain gunpowder being so rapid, the expansion of the gases is so quick, that the whole power is generated and has reached its highest point before the bullet can be much more than half way out of the barrel; leaving it without any increasing propellant power, than that which has been already generated, to contend with the column of air in the remaining part of the barrel, which must be condensed before the bullet can leave the muzzle. The consequence is, that a high speed is quickly generated, to be again quickly reduced to a lower velocity by the opposition of the air in the other part of the barrel, as well as by the friction of the bullet. It is, as already stated, too quick to be beneficial; it kicks the bullet, as it were, out of the barrel, and does not communicate to it the *momentum* which the bullet would otherwise receive if the impulse were graduated.

A properly graduated impulse may, however, be at all times obtained by using a certain quantity of powder of a larger grain; for, as it does not explode so rapidly, *it would generate a power, expanding from breech to muzzle, increasing the velocity of the bullet on a graduated scale, by the accumulation of the powder gases, until it obtained its highest or maximum velocity just as it left the muzzle of the rifle;* for the duration of the ex-

plosion, or the period during which a continuous generating of force is obtained, is dependent upon the size or quantity of matter in each individual grain. The combustion of the whole quantity will, therefore, be lengthened or shortened as the grains are larger or smaller.

Under the head of "A few points essential for good combinations," Mr. Chapman says, "it also appears that the bullets require a certain amount of friction, in moving along the bore, to ensure the most perfect delivery at the muzzle; and this amount of friction must never be reduced so as to allow the flame of the powder to pass by the bullet, an error into which Mr. Wesson fell in 1844." In this remark we have the clearest evidence of some of the evils which attend the "freed-bore" system. Mr. Wesson, imagining that all the powder is *instantaneously* fired, and the bullet as *suddenly* expanded into the grooves, originally adopted the plan of "what is technically called *freeing* the bore from the breech to within $1\frac{1}{2}$ inches of the muzzle, so as materially to reduce the friction of the bullet and patch in passing out when the weapon is fired." He afterwards, however, attempted to reduce the supposed extra amount of friction, by freeing the bore still further; the result of which naturally was, that a larger proportion of the gases was permitted to escape past the bullet, and the shooting consequently rendered inferior.

This was certainly carrying the freeing system to an extreme; but still, it ought to convince anyone who is not wilfully blinded that, if this proved so

decided a failure, faults more or less must attend the principle generally. In this case, the widening of the bore towards the breech was carried to such an extent that the gases not only escaped in larger quantities, but the bullet must have been driven far up the barrel before it entered the grooves. It is in consequence of this, no doubt, that we often pick up bullets which have gone wide of the mark, and, on examination, find that they have apparently entered the grooves; but we are quite unable to say if they did so *sufficiently early* to obtain the proper amount of rotatory motion. It is with reference to this part of the subject that Mr. Chapman remarks (though apparently unconscious that the fault lies in the "freeing" system), that "some weapons require the lead to be hardened, whilst others seem to perform the best with the very softest." "The cause of this," says he, "I am not thoroughly master of; but, as a general rule, rifles cut with *deep* creases, and *much freed*, require the soft lead, and those cut *shallow* and *moderately freed*, the hard." True, most true; for there would be very little use in trying hardened lead in a "*much freed*" bore with "*deep* creases," though it is less liable to upset, and therefore, if not too hard, will shoot better from a cylindrical bore with shallow grooves.

In writing a short treatise on rifles, or rifle projectiles, it is almost impossible to do so without being guilty of some *apparent* inconsistencies; the limits of the work admitting of very brief explanations. But one cannot help being surprised that the author of

"The American Rifle" should have admitted into his otherwise very clever work so many glaring contradictions, without more consideration. Some of his most valuable hints are quite distorted, by being mixed up and placed side by side with doctrine so inconsistent that it seems difficult to believe the whole to have been written by the same person. In fact, the most correct principles seem to have acquired a doubtful character from the company in which they are found. "I am inclined," says he, "to think that our rifle bullets get a considerable start before the whole blast of the exploded powder operates fully upon them." Here we have an opinion, though expressed in a casual manner, which is worthy of a thorough rifleman; but how are we to reconcile it, and some others of a like nature, with those *leading* "principles" which I have already quoted and might further quote?

Mr. Chapman's great fault appears to be an implicit belief in the efficacy of large charges of powder, so as to *start* the bullet with the highest possible velocity; and to this doctrine all others are made to bow. "After all the requisites are complied with," he says, "it is certain that the charge of powder, *consequently the velocity*, is limited by the upsetting of the lead." Had he thrown aside many ideas like this, which have evidently been borrowed, and made a more general application of his own opinions, which are on most points very apposite, it would have added greatly to the value of his work. The "*freed* bore" system, as well as the "gaining twist," would have

been abandoned, and classed, as a matter of course, among the "deficiencies and superfluities"—which, he says, are constantly being replaced by "additions and alterations"—in the American rifle. Had he done this, his treatise would have been rendered more consistent throughout; and he would have had less reason for concluding, as he has done, in the following melancholy strain:—"After the most careful attention to all the essential points in combination [*query*], with all the assistance that can be obtained from the best mechanics of the age, so far as construction is concerned, we are compelled at last to writhe under the lash of imperfection. There is nothing perfect in the work of man. We discover at last that we have the perception of perfection, but the thing itself is denied us. We may imitate the motion of the earth, by giving the bullet a rotary as well as a progressive motion, but we cannot make the lines of flight coincide, and we end as we began—in error."

To go regular and *straight* along the barrel—that is, the axis of the bullet keeping in a line with the axis of the bore—it is desirable and necessary that the bullet should *fill* the cylinder as much as possible *next* the powder. But how can this be accomplished in a *freed* bore, the sides of which, correctly speaking, cannot bear on all sides of the bullet with the necessary amount of pressure? A moment's consideration will show that this is practically impossible. The bullet must be made small enough to enter the muzzle freely; and, though it may be carefully pressed down on the powder, it will be then placed in a wider space,

and will, in all probability, be *pressed* more to one side of the barrel than the other, or, very likely, be *inclined* to one side or the other. Besides this, the moment the rifle is brought to the horizontal position, gravity will cause the bullet to press more on the *under* than the upper side of the barrel: the consequence will be, that though the difference of pressure, or inclination, may be insignificantly small at the first, it will be quite enough—the bullet not being instantaneously expanded—to permit of a more or less escape of the gases; which, on account of their great elasticity, will rush over the upper side of the bullet, deranging its position still further. A deviation in the flight of the bullet will, therefore, be often the result: and the greater the range, the greater the deviation will be; for the greater in increasing proportion will the smallest errors and casualties be multiplied. The method of deepening the grooves next the breech is an additional evil; for the fluid will move much quicker through all these openings, and past the sides of the bullet, than the bullet itself ever can move. Hence, the diminution of the impelling force must be even more considerable, and must necessarily make the velocity of the bullet much less than what it would otherwise be, if the grooves were shallow and the bullet fitted the bore.

It is difficult to induce some people to abandon what have become "set or fixed notions"; but, if calmly considered, there cannot be a doubt but that the plan of *freeing* the bore and *deepening* the grooves next the breech is erroneous in principle, and that

serious evils attend it. I have endeavoured to describe the *motions* of an elongated bullet, and the *action* of the gunpowder *inside* the barrel. Let any unprejudiced rifle maker meet this half-way, by *adapting* some of his best rifle barrels to these motions; the result will show that his reliance on the recommendation has not been misplaced. Let him bear in mind, that the resistance to the progress of a bullet, when passing up the barrel, by friction and the condensed air, is *exceedingly* great, if the bullet fits properly. Instead, therefore, of contriving to increase this friction, "for the purpose," as Mr. Chapman absurdly remarks, "of *retarding* the bullet as it approaches the muzzle, so that the full effect of the expansive power of the powder may be communicated to it"; I say, *lessen* the friction by every possible means consistent with the *true fitting* of the bullet.

Let the barrel be made a true cylinder from end to end; so that, if the bullet fits properly and is inserted carefully, at the muzzle, it may be *pressed* as truly down (but *lightly*) on the powder. Let the grooves be four or five in number; for, with *hollow* bullets, it matters little whether they be odd or even —that is, whether they be *opposite* to one another or not. Let the lands be only half the breadth of the grooves; for it is a law in mechanics, that "*the smallest surface has the least friction, the pressure being the same.*" By making the lands narrow, the friction in loading, and any annoyance from fouling, will be very much reduced. In firing, the friction will also be greatly reduced; because, when the bullet is in

the *act* of expanding, the friction will be on the lands alone; and even after, when the expansion is complete, the *intensity* of the pressure will be more on the lands than in the grooves; the particles of matter which compose the bullet being pressed closer together by the resistance of the lands than by the grooves. Instead of deepening the grooves at the breech, let it be the very reverse; begin almost *nil* at the breech, and gradually deepen them for four or five inches, until the desired depth is obtained; but on no account make them *deep*. By adopting this plan, as the bullet is not *instantaneously* expanded at the breech, the elastic fluid will not be permitted to escape through the grooves; its force will therefore be expended in propelling the bullet; and consequently, a greater velocity, a greater range, and a lower trajectory, will be the result. For the same reason—that the bullet is not instantaneously expanded—the American plan of having a spiral with a "gaining twist" is not only superfluous, but is calculated to *jam* and *upset* a leaden bullet as it approaches the muzzle, where it is at its highest velocity. A *regular* spiral, therefore, of one turn in from six to eight feet, will be found to be the best for all ranges; though, according to Mr. Chapman, an American rifleman, in order to make first-rate shooting at all distances, should have a *variety* of rifles, constructed in a different manner for every additional hundred yards.

ON A VACUUM BEING CREATED BEHIND A BULLET IN THE AIR, WHEN IT MOVES WITH A CERTAIN VELOCITY.

At pages 33 and 44 it is stated that the pressure of the atmosphere is taken entirely off the hinder part of the bullet when it moves faster than the particles of air can follow by rushing into the place quitted and left void by the bullet; that is, when the bullet moves with a greater velocity than air rushes into a vacuum. In reply to certain querists, I shall here endeavour to explain how this velocity may be ascertained.

The atmosphere or mass of air which surrounds the earth is a fluid acted on by gravity, and presses upon all bodies immersed in it in accordance with the general laws of fluid pressure. It is found by experiment that the pressure which the atmosphere exerts upon a body on or near the surface of the earth is the same as that exerted by a column of mercury of from 29 to 30 inches in height, or by a column of water of from 33 to 35 feet in height; that is, it presses with a weight of about 15lbs. upon every square inch of surface.

This is proved by the common barometer, for on this principle that instrument is constructed. In fair and settled weather the mercury in the barometer is as high as 30 inches; it is sometimes higher, but it seldom rises so high as 31; when it falls to 29½, a change is usually expected; but it seldom sinks so low as 28, except in very stormy weather.

Suppose, then, the mercury to be as high as 30 inches, and suppose that the tube of the barometer is uniform, and the area of the bore of the tube equal to one square inch; the column of mercury in the tube will amount to 30 cubic inches, and this quantity will be found to weigh very nearly 15lbs. avoirdupois.

As the column of mercury in the tube is balanced or held in equilibrium by the weight of a column of the atmosphere of the same diameter, but whose height is equal to the whole height of the atmosphere above the earth's surface; it follows that, if 30 cubic inches of mercury weigh nearly 15lbs., the pressure of the air upon every square inch of surface will be the same—that is, nearly 15lbs.

I have supposed the area of the bore of the tube to be equal to one square inch: but the height of the column of mercury sustained by the atmospheric pressure will be the same, whatever be the magnitude of the bore of the tube; for if there be another tube, whose bore is only half a square inch, then the pressure which will support the column in it will be that of a similar column of atmosphere, whose base is half a square inch; such pressure then will only be half the amount of the former, and therefore will only sustain half the weight of mercury; but a column of mercury of half the weight, having a base of half the magnitude, must necessarily have the same height: so long, therefore, as the atmosphere presses upon a given magnitude of the surface with the same intensity, the column of mercury sustained in the tube will have the same height, whatever be the magnitude of its bore.

That we are not, in ordinary circumstances, cognizant of this pressure, arises, as I have already remarked (page 45), from the characteristic property of fluids, in accordance with which they press in all directions upon bodies immersed in them. The atmosphere, as we have seen, presses with a weight which is equal to 15lbs. on every square inch of surface. Hence our bodies must sustain an enormous pressure: and though we are not immediately sensible of this, yet we may easily become so; for let the equality of the pressure to which our bodies are subject be destroyed by the removal of the air from any one portion of the body, then we are immediately made sensible of the enormous pressure which the rest sustains. For instance: let the air be exhausted by the air-pump from beneath a hand, which is placed over the open top of a cylindrical receiver; then the hand will be pressed down so firmly on the edges of the vessel that it will be impossible to move it. The body of a man, the surface of which amounts to 2,000 square inches, will sustain a pressure from the surrounding air to the enormous amount of 30,000lbs. It might at first view be expected that this great force to which all bodies are subject would produce manifest effects, so as to crush, compress, or break them, whereas we find bodies of most delicate texture unaffected by it. Thus a close bag, made of the finest silver paper, and partially filled with air, is apparently subject to no external force. Its sides do not collapse. This arises partly from the circumstance of the pressure on every side and in every direction being equal,

and therefore producing mechanical equilibrium. "The elastic force of the air is equal to its pressure"; the air, therefore, which is confined in the bag, has precisely the same tendency to swell the bag, and to keep the parts asunder, as the external pressure of the atmosphere has to make them collapse. In the same manner we may account for the fact that animals move freely in the air without being sensible of the enormous pressure to which their bodies are subject. The internal parts of their bodies are filled with fluids, both in the liquid and gaseous states, which offer a pressure from within exactly equivalent to the external pressure of the air. The *pressure* and *elasticity* of the air are both exercised in the act of breathing. When we draw in the breath, we first make an enlarged space in the chest. The pressure of the external atmosphere then forces air into this space, so as to fill it. By a muscular action the lungs are next compressed, so as to give this air a greater elasticity than the pressure of the external atmosphere. By the excess of this elasticity it is propelled, and escapes by the mouth and nose. It is obvious, therefore, that the air enters the lungs not by any direct act of these upon it, but by the weight of the atmosphere forcing it into an empty space, and that it is expired by the action of the lungs in compressing it.

The specific gravity of bodies vary with their temperature; for most bodies expand by heat, and are contracted again in cooling. It follows, then, that bodies of unequal specific gravities will weigh

differently in different states of the atmosphere. When the mercury in the barometer stands at 30 inches, and the thermometer at 55 degrees, it has been found that the specific gravity of

Mercury is 13,600
Water „ 1,000
Air „ 1¼ or 1⅛

that is, a cubic foot of each will weigh so many ounces.

From this it will be perceived that mercury is nearly 14 times heavier than water. If, therefore, the fluid in the tube were water, the height of the column would be nearly 14 times 30—that is, 420 inches, or 35 feet: but, more correctly, 34 feet, supposing the tube were long enough; for the weight or pressure of the atmosphere is, as already stated, equal to that of a column of water from 33 to 35 feet high, or of mercury from 29 to 30 inches, at a medium state of the air; and as water and mercury are in weight nearly as 1 to 14, the atmosphere will balance a column of water nearly 14 times as high as one of mercury.

Water is non-elastic, or all of a uniform density; but the atmosphere, from its expansive and elastic quality, becomes continually more and more rare, in a certain proportion, the higher we ascend above the level of the sea. But supposing that the atmosphere were *homogeneous*—that is, all of uniform density, like water; or, in other words, if it were of the same density at all altitudes as at the earth's surface—its height would be between 5 and 6 miles.

For example: if $1\frac{1}{5}$, the specific gravity of air, is equal in bulk to 1000, the specific gravity of water; so 34 feet of water will be equal in weight to 28,322 feet, or $5\frac{1}{4}$ miles fully of air.

Again: if $1\frac{1}{5}$, the specific gravity of air, is equal in bulk to 13,600, the specific gravity of mercury, so 30 inches of mercury will be equal in weight to 339,990 inches (that is, 28,332 feet, or $5\frac{1}{4}$ miles) fully of air; being the height of a homogeneous atmosphere whose pressure would be equal to that of the real atmosphere.

Now, with reference to the pressure of water, it is a fact established by experiment that the velocity with which it runs out of a hole in the bottom or side of a vessel is equal to that which is generated by gravity through the height of the fluid above the hole—that is, it is equal to the velocity which a body would acquire in descending freely from rest through the perpendicular height; for the force in this case is the weight of the superincumbent column of the fluid over the hole, and depends on its altitude above the hole, the pressure being at its height. And as this fact applies equally to the pressure of the air when rushing into a vacuum, the following rule must be applied, in either case, in order to ascertain the velocity sought:—

Rule. The velocity is equal to the square root of the product of twice the space through which the body falls, and the velocity acquired by falling for one second.

If the fluid, therefore, were air, of the whole

height of the atmosphere, supposed uniform—which is, as already stated, about $5\frac{1}{4}$ miles, or 339,990 inches, equal to 28,332 feet—we shall have $\surd(2 \times 28332 \times 32\frac{1}{6}) = 1350$ feet, the velocity per second with which common air near the earth's surface would rush into a vacuum, from the pressure of the incumbent air.

This may probably be rendered more intelligible by the following method of calculation:—

28332 feet, the height of a uniform atmosphere
2

56664 feet, the product of twice the above space
$32\frac{1}{6}$ feet, the velocity which a body acquires in falling for one second

113328
169992
9444 square root

1822692(1350 feet, the velocity sought.
169

265 | 1326
1325

192

As the air, therefore, rushes into a vacuum with a velocity of 1,350 feet per second—or a little more or less, according to the state of the barometer and thermometer at the time—it follows that when a bullet flies at any velocity higher than that rate, it must leave a vacuum behind it.

